NOTICE

All drawings located at the end of the document.

DRAFT FINAL

PHASE I RFI/RI WORK PLAN

PRESENT LANDFILL (SWMU 114)
AND INACTIVE HAZARDOUS WASTE
STORAGE AREA (SWMU 203)
OPERABLE UNIT NO. 3
ROCKY FLATS PLANT

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

ENVIRONMENTAL RESTORATION PROGRAM

JUNE 4, 1990

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This document presents the work plan for a Phase I RCRA Facility Investigation/Remedial Investigation (RFI/RI) for two Solid Waste Management Units (SWMU) in Operable Unit (OU) No. 3, the Present Landfill (SWMU 114), and the Inactive Hazardous Waste Storage Area (SWMU 203) at the Rocky Flats Plant.

Previous studies at the landfill site have identified the presence of contamination that potentially could impact human health and the environment if releases occurred from the landfill. Corrective measures are anticipated for the landfill and therefore, an RFI/RI is required to determine the nature and extent of contamination associated with the site. The Phase I Work Plan addresses characterization of source materials and soils in the area of these units. A subsequent Phase II plan will focus on groundwater contamination and the nature and extent of contaminant migration.

The Present Landfill (SWMU 114) is located to the north of the plant security area on the western end of an unnamed tributary of North Walnut Creek. Landfill operations were initiated in August 1968. The landfill was designed for disposal of the Plant's nonradioactive solid waste, including paper, rags, floor sweepings, cartons, mixed garbage and rubbish, demolition materials, and miscellaneous items. Little testing has been performed to characterize the in-place wastes. However, in 1986 and 1987, studies were conducted to identify waste streams generated at the Rocky Flats Plant. Approximately 1,500 waste streams were identified. At the time of the study, 338 of these waste streams were being sent to the landfill for disposal. These included 241 waste streams identified as nonhazardous solid waste and 97 waste streams that contained hazardous waste or hazardous constituents. The hazardous waste constituents included paints, solvents, degreasers, oil filters, and metal cuttings and shavings, including mineral and asbestos dust, and miscellaneous metal chips coated with oils and carbon tetrachloride.

In addition to the hazardous waste constituents buried in the landfill, tritium was detected downstream of the landfill in 1973. In response, monitoring wells were installed directly in the landfilled waste materials. Elevated tritium readings were found in the landfill leachate, and the approximate location of the source was identified. The tritium concentrations in the leachate near the suspected tritium source ranged up to 301,609 pCi/l. The depth of the tritium source, total activity, configuration, and container, if any, are unknown. It is believed that the waste containing the source was placed in the landfill during 1970.

The Inactive Hazardous Waste Storage Area (SWMU 203) is located on the southwest corner of the Present Landfill and was actively used between 1986 and 1987. This area was operated as a hazardous waste storage area for drummed liquids and solids. Fifty-five-gallon drums with free liquids were stored within 14 cargo containers. One additional container was used to store spill control items such as oil sorbent and sorbent pillows. RCRA wastes were stored in 12 of the 14 cargo containers and included solvents; coolants; machining wastes; cutting and lubricating oils; and organics and acids. The remaining two cargo containers were used to store polychlorinated biphenyl (PCB) contaminated soil and debris, as well as PCB contaminated oil from transformers taken out of service. Some storage of drummed solids (55-gallon containers) took place outside the cargo containers. According to the 1988 Inactive Interim Status Closure Plan for SWMU 203 (Rockwell International 1988c), small spills of less than reportable quantities occurred in this area during transfer operations.

Since little direct characterization of the types of contaminants in the landfill has been conducted to date, most of what is known is based on waste stream identification studies and groundwater and surface water quality monitoring. Previous evaluations of groundwater quality from wells at the periphery of the landfill indicate the landfill contributes calcium, bicarbonate, and to a lesser extent, sulfate, iron, manganese, zinc, and strontium to the groundwater. Volatile organic contamination, primarily TCE and 1,1,1-TCA, has been found sporadically and at low concentrations in groundwater in some areas at the landfill periphery. The previous evaluations of groundwater quality were conducted for the 1989 Annual RCRA Groundwater Monitoring Report for Regulated Units at Rocky Flats Plant (EG&G 1990a) using background water quality results from the Draft Background Geochemical Characterization Report for the plant site (Rockwell International 1989e). As is typical of sanitary landfills, groundwater quality has been impacted through increased major ion, iron, manganese, and zinc concentrations. Elevated uranium and tritium levels also exist in some areas. Soil contamination at SWMU 203 has not been characterized.

The primary mechanism for release of contaminants from the Present Landfill into the affected media appears to be by percolation of groundwater (leachate) through the wastes and then out of the landfill. Leachate occurs within the landfill as a result of infiltration of precipitation and also possibly from infiltration of groundwater through or beneath the existing perimeter groundwater diversion system. Groundwater flow exiting the wastes can potentially distribute contamination vertically downward and laterally downgradient. In the case of the inactive storage area, any spilled material could be released by percolation into the landfill wastes. Wind dispersal of gases or contaminated dust may act as another release mechanism.

Evaluation of the existing data concerning both the Present Landfill and the Inactive Hazardous Waste Storage Area has resulted in five general conclusions, as presented in the 1988 Closure Plan (Rockwell International 1988b) and 1988 Present Landfill Hydrogeologic Characterization Report (Rockwell International 1988d). These conclusions form the basis for the development of field activities to be implemented during the Phase I remedial investigation.

1. Existing groundwater level data indicate that water occurs within the landfill wastes.

2. The water within the landfill is the result of groundwater infiltration into the landfill and/or percolation of surface water through the waste.

3. Migration of groundwater from the landfill may have resulted in contaminated soils beneath and possibly downgradient of the landfill.

4. Soils at the Inactive Hazardous Waste Storage Area may be contaminated with organics, metals, and radionuclides. At present, the contamination, if any, is believed to be concentrated near the ground surface; therefore, delineation of the extent of contamination is needed.

5. Metals, radionuclide, and some limited organic contaminants have been identified in groundwater from wells adjacent to the landfill. Existing data on the source materials are limited, and data on soil contamination are nonexistent.

The Phase I RFI/RI is the first step in evaluating the potential threat to the public's health and the environment as a result of the potential release of contamination from the landfill. Ultimately, the RFI/RI process will provide justification for performing or not performing remedial actions.

Phase I, characterization of source and soils, serves to initiate the evaluation process for developing remedial technologies to be used at the Present Landfill if a risk assessment deems remediation necessary.

Because of the variability of landfill wastes, it would be exceedingly difficult to adequately characterize them based solely on discrete borehole sampling and analytical testing of the wastes. Discrete waste samples are difficult to obtain and analytical procedures have not been established to quantify contaminant levels for materials such as paper or metal containers. Therefore, characterization of the source will be accomplished by sampling and testing the pore fluids (leachate and soil gas) from wells installed in the wastes. For Phase I source characterization, it is assumed that the landfill leachate and soil gas are representative of what will be generated in the future and that they will provide an indication of leachable or mobile compounds present in the waste. The evaluation of leachate and soil gas for source characterization will be supplemented by a comparison of upgradient with downgradient groundwater quality based on samples from existing wells and sediment sampling near the upstream end of the landfill pond.

The physical properties and contamination of the soils beneath and downgradient of the source will be evaluated by laboratory analyses on soil samples. Soil fill beneath the waste fill, natural alluvial and colluvial soils, and weathered bedrock will be sampled and analyzed. The field investigation will include drilling 15 boreholes with collection of continuous soil samples for analytical testing. Monitoring wells will be constructed at 10 of the borehole locations for sampling and analysis of leachate.

Sampling activities at the Inactive Hazardous Waste Storage Area (SWMU 203) will include visual inspection and radiological and organic vapor screening to locate possible spill sites within the area. Surficial soil sampling will also be conducted to determine the extent and magnitude of soil contamination in this area, if any.

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1.0
INTRODUCTION

This document presents the work plan for a Phase I RCRA Facility Investigation/Remedial Investigation (RFI/RI) for two Solid Waste Management Units (SWMU), the Present Landfill (SWMU 114), and the Inactive Hazardous Waste Storage Area (SWMU 203) in Operable Unit (UO) No. 3 at the Rocky Flats Plant. This work plan addresses characterization of source materials and soils. A subsequent Phase II RFI/RI will focus on groundwater contamination and the nature and extent of contaminant migration.

This investigation is part of a comprehensive, phased program of site characterization, Remedial Investigations/Feasibility Studies (RI/FS), and remedial actions currently in progress at the Rocky Flats Plant. These activities are being administered by the U.S. Department of Energy (DOE), Environmental Restoration (ER) Program, pursuant to an Inter-Agency Agreement (IAG) (DOE 1989) stipulated among DOE, the U.S. Environmental Protection Agency (EPA), and the Colorado Department of Health (CDH). The IAG addresses Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) issues and has been integrated within the ER Program. In accordance with the draft IAG, the CERCLA terms Remedial Investigation and Feasibility Study in this document are considered equivalent to the RCRA terms RCRA Facility Investigation (RFI) and Corrective Measures Study (CMS).

1.1 ENVIRONMENTAL RESTORATION PROGRAM

The ER Program is designed to investigate and clean up contaminated sites at DOE facilities. The ER Program is being implemented in five phases. The initial phase (Installation Assessment) includes preliminary assessments and site inspections to assess potential environmental concerns. The second phase (RFI/RI) includes planning and implementation of sampling programs to delineate the magnitude and extent of contamination at specific sites and evaluate potential contaminant migration pathways. The third phase (FS/CMS) evaluates remedial alternatives and develops remedial action plans to mitigate environmental problems identified as needing correction in the second phase. The fourth phase (Remedial Design/Remedial Action) includes design and implementation of site-specific remedial actions selected on the basis of the FSs/CMSs. The fifth phase (Performance Assessment) implements monitoring and performance assessments of remedial actions, and verifies and documents the adequacy of remedial actions carried out under the fourth phase. The initial phase has already been completed at the Rocky Flats Plant (U.S. DOE 1986). This Phase I Work Plan initiates the second phase of the ER Program implementation for the Present Landfill.

Previous studies at the Present Landfill have identified the presence of contamination that could potentially impact human health and the environment if releases occurred from the landfill. Corrective measures are anticipated for the landfill and, therefore, an RFI/FI is required to determine the full nature and extent of contamination associated with the site.

1.2 WORK PLAN SCOPE

This Phase I RFI/RI Work Plan presents a summary of existing data and a sampling plan for soil and source characterization. It does not address an assessment of the nature and extent of groundwater contamination, although groundwater quality data are used as a means for evaluating the source. Groundwater will be addressed by a Phase II RFI/RI. SWMU 203 is included in this RFI/RI since it is situated on top of the landfill. For the Phase I evaluation, the ground surface at SWMU 203 will be evaluated individually. However, it is assumed that the baseline risk assessment and alternatives evaluation for the landfill will include SWMU 203 unless the Phase I evaluation indicates significant contamination requiring individual consideration of SWMU 203. Similarly, it is assumed the Phase I RFI/RI does not need to address the east landfill pond. If Phase I sampling of leachate and pond sediments finds significant contamination, Phase II will address the pond as part of evaluating the extent of contamination. Data were compiled from a number of sources. The following previous studies were the primary sources used in preparing the work plan. A more complete list of references is presented in Section 8.0.

- Background Geochemical Characterization Report (Rockwell International 1989c) (Appendix D to this work plan)

- Annual RCRA Groundwater Monitoring Reports (Rockwell International 1989a, EG&G 1990a) (Appendixes E and F, respectively, to this work plan)

- Present Landfill Closure Plan (SWMU 114) (Rockwell International 1988b)

- Closure Plan, Inactive Interim Status Facilities, Hazardous Waste Storage Area (SWMU 203) (Rockwell International 1988c)

- Present Landfill Hydrogeologic Characterization Report (Rockwell International 1988d, Appendix 6 to Rockwell International 1988b) (Appendix A to this work plan)

Preparation of this work plan involved limited additional evaluation of existing data. The work plan will serve as a framework for more rigorous RFI/RI activities, including detailed evaluation of existing data, that will be conducted independently or as part of the RFI/RI process. This framework was established in accordance with EPA RI/FS guidance (U.S. EPA 1988a).

The Phase I RFI/RI is intended to obtain information to sufficiently characterize the source and soils for preliminary (Phase I) evaluation. Although detailed sampling and analysis of the source and soils will be conducted, the level of information obtained will not necessarily be sufficient for detailed alternatives analysis or to support a no action alternative. It is possible that further soil and source characterization will be required as part of Phase II RFI/RI work.

Section 1.0 of this work plan presents introductory information and a general characterization of the region and plant sites. Section 2.0 presents a preliminary characterization and conceptual model for the Present Landfill site based on existing data. The identification of preliminary alternative actions for remediation of the source, Section 3.0, was based on experience and represents the range of actions normally implemented at landfill sites. The discussion of Applicable or Relevant and Appropriate Requirements (ARAR) presented in Section 4.0 indicates ARARs are being developed on a site-wide basis. The Baseline Risk Assessment Plan (BRAP) and the Environmental Evaluation Plan (EEP) (both included in Section 6.0), were reproduced with minor editing from the previous Phase II and Phase III Work Plans from the 903 Pad and 881 Hillside projects, respectively. Preliminary identification of data needs and Data Quality Objectives (DQO) (Section 5.0) were developed considering the preliminary site characterization and conceptual model. A Field Sampling Plan (Section 7.0) was then developed, based on the existing data, to satisfy the data needs and data quality objectives for further characterization of the soils and source.

1.3 REGIONAL,AND PLANT SITE BACKGROUND INFORMATION

1.3.1 Background

The Rocky Flats Plant is a government-owned contractor-operated (GOCO) facility, which is part of the nationwide nuclear weapons production complex. The Plant was operated for the U.S. Atomic Energy Commission (AEC) from its inception in 1951 until the AEC was dissolved in January 1975. At that time, responsibility for the Plant was assigned to the Energy Research and Development Administration (ERDA), which was succeeded by the DOE in 1977. Dow Chemical U.S.A., an operating unit of the Dow Chemical Company, was the prime operating contractor of the facility from 1951 until June 30, 1975. Rockwell International followed Dow Chemical as the operator, beginning July 1, 1975, and EG&G Rocky Flats, Inc. succeeded Rockwell on January 1, 1990.

The primary mission of the Rocky Flats Plant is to fabricate nuclear weapon components from plutonium, uranium, beryllium, and stainless steel. Parts made at the Plant are shipped elsewhere for assembly. In addition, the Plant reprocesses components after they are removed from obsolete weapons for metals recovery.

Both radioactive and nonradioactive wastes are generated in the production process. Current waste handling practices involve onsite and offsite recycling of hazardous materials, onsite storage of hazardous and radioactive mixed wastes, and offsite disposal of solid radioactive materials at another DOE facility. However, both storage and disposal of hazardous and radioactive wastes occurred onsite in the past. Preliminary assessments under the ER Program identified some of the past onsite storage and disposal locations as potential sources of environmental contamination.

1.3.2 Physical Setting

The Rocky Flats Plant is located in northern Jefferson County, Colorado, approximately 16 miles northwest of Denver, Colorado (Figure 1-1). The Plant consists of approximately 6,550 acres of federal land in Sections 1 through 4 and 9 through 15 of T2S, R70W, 6th Principal Meridian. Major buildings are located within the plant security area of 384 acres. The security area is surrounded by a buffer zone of approximately 6,150 acres (Figure 1-2).

1.3.2.1 Climate

The Rocky Flats Plant has a semiarid climate typical of the Rocky Mountain region. However, the elevation of the plant and the nearby slopes of the Front Range slightly modify the regional climate.

Winds at Rocky Flats Plant, although variable, are predominantly from the west-northwest. Stronger winds occur during the winter, and the area occasionally experiences Chinook winds with gusts up to 100 miles per hour because of its location near the Front Range (U.S. DOE 1980). Figure 1-3 shows the wind direction, frequency, and average velocity for each direction as recorded in 1988 (Rockwell International 1989b).

Temperatures at Rocky Flats Plant are moderate. Extremely warm or cold weather is usually of short duration. On the average, daily summer temperatures range from 55 to 85 degrees Fahrenheit (F), and winter temperatures range from 20 to 45 degrees F. Temperature extremes recorded at the plant have ranged from 102 degrees F on July 12, 1971 to -26 degrees F on January 12, 1963. The 24-year daily average maximum temperature for the period 1952 to 1976 was 76 degrees F, the daily average minimum was 22 degrees F, and the average annual mean was 50 degrees F. Average relative humidity was 46 percent (U.S. DOE 1980).

Based on precipitation averages collected between 1953 and 1976, the mean annual precipitation at the Plant is 15.16 inches. Approximately 40 percent of the precipitation falls during the spring season, much of it as snow. Thunderstorms from June to August account for an additional 30 percent of the precipitation. Autumn and winter are drier seasons, accounting for 19 and 11 percent of the annual precipitation, respectively. Snowfall averages 85 inches per year, generally occurring between October and May (U.S. DOE 1980).

Special attention has been focused on dispersion meteorology surrounding the plant because of the remote possibility that significant atmospheric releases might affect the Denver metropolitan area. Studies of air flow and dispersing characteristics (for example, Hodgin 1983 and 1984) indicate that drainage flows (winds coming down off of the mountains to the west) turn and move toward the north and northeast along the South Platte River valley and pass to the west and north of Brighton, Colorado. These drainage flows are of particular interest because they occur under stable atmospheric dispersion conditions (generally at night) when atmospheric mixing is limited (Rockwell International 1986a).

1.3.2.2 Regional and Local Geology

Geologic units at the Rocky Flats Plant (in descending stratigraphic order) are the surficial units (Rocky Flats Alluvium, various terrace alluviums, valley fill alluvium, and colluvium) and bedrock (Arapahoe Formation, Laramie Formation, and Fox Hills Sandstone). Figure 1-4 presents a generalized east-west geologic cross section of the region. The Denver Formation does not occur in the vicinity of the plant. Groundwater occurs under unconfined conditions in both the surficial and upper Arapahoe Formation bedrock units. In addition, confined groundwater flow occurs in bedrock sandstones.

1.3.2.2.1 Rocky Flats Alluvium. The Rocky Flats Alluvium underlies a large portion of the Plant. The alluvium is a broad planar deposit consisting of a topsoil layer underlain by up to 100 feet of silt, clay, sand, and gravel. Unconfined groundwater flow occurs in the Rocky Flats Alluvium, which is relatively permeable compared to claystone, siltstone, and silty sandstone. Recharge to the alluvium is from precipitation, snowmelt, and water losses from ditches, streams, and ponds that are cut into the alluvium. General water movement in the Rocky Flats Alluvium is from west to east and toward the drainages. Groundwater flow is also controlled by buried channels in the top of bedrock. Groundwater in the Rocky Flats Alluvium generally rises in response to recharge during the spring and declines during the remainder of the year. Discharge from the alluvium occurs at seeps in the colluvium that covers the contact between the alluvium and bedrock along the edges of the valleys, and into the underlying bedrock. In general, the Rocky Flats Alluvium thins from west to east and does not directly supply water to wells located downgradient of Rocky Flats Plant (Rockwell International 1989d).

1.3.2.2.2 Other Alluvial Deposits. Various other alluvial deposits occur topographically below the Rocky Flats Alluvium in the Plant drainages. Colluvium (slope wash) mantles the valley side slopes between the Rocky Flats Alluvium and the valley bottoms. In addition, remnants of younger terrace deposits including the Verdos, Slocum, and Louviers Alluviums occur occasionally along the valley side slopes. Recent valley fill alluvium occurs in the active stream channels.

Unconfined groundwater flow occurs in these surficial units. Recharge is from precipitation, percolation from streams during periods of surface water runoff, and by seeps discharging from the Rocky Flats Alluvium. Discharge is by evapotranspiration and by seepage into other geologic formations and streams. The direction of groundwater flow is generally downslope through colluvial materials and then along the course of the stream in valley fill materials. During periods of high surface water flow, water is lost to bank storage in the valley fill alluvium and returns to the stream after the runoff subsides.

1.3.2.2.3 Arapahoe Formation. The Arapahoe Formation underlies surficial materials beneath the Plant. The Arapahoe consists mostly of claystone with some channel sandstones. Total formation thickness varies up to 270 feet (Robson et. al., 1981). The channel sandstones are composed of fine-grained sands and silts, and their hydraulic conductivity is low compared to the overlying Rocky Flats Alluvium.

The Arapahoe Formation is recharged by leakage from streams and groundwater movement from overlying surficial deposits. The main recharge areas are under the Rocky Flats Alluvium, although some recharge from the colluvium and valley fill alluvium likely occurs along the stream valleys. Recharge is greatest during the spring and early summer when rainfall and stream flow are at a maximum and water levels in the Rocky Flats Alluvium are high. Groundwater movement in the Arapahoe Formation is generally toward the east; although flow within individual sandstones is not fully characterized at this time. Regionally, groundwater flow in the Arapahoe Formation is toward the South Platte River in the center of the Denver Basin (Robson et. al. 1981a).

1.3.2.2.4 Laramie Formation and Fox Hills Sandstone. The Laramie Formation underlies the Arapahoe and is composed of two units, a thick upper claystone and a lower sandstone. The claystone is greater than 700 feet thick and is of very low hydraulic conductivity; therefore, the U.S. Geologic Survey (Hurr, 1976) concluded that Plant operations will not impact any geologic units below the upper claystone belonging to the Laramie Formation (Rockwell International 1989d).

The lower sandstone unit of the Laramie Formation and the underlying Fox Hills Sandstone comprise a regionally important aquifer in the Denver Basin known as the Laramie-Fox Hills Aquifer. These units subcrop west of the Plant and can be seen in clay pits excavated through the

Rocky Flats Alluvium. The steeply dipping beds (45 to 50 degrees) of these strata quickly flatten to less than 2 degrees to the east. Recharge to the aquifer occurs along the rather limited outcrop area exposed to surface water flow and leakage along the Front Range (Robson et. al., 1981b).

1.3.2.2.5 Surface Water Hydrology. Three ephemeral streams drain the Rocky Flats Plant with flow generally from west to east. These drainages are Rock Creek, Walnut Creek, and Woman Creek (Figure 1-2). Rock Creek drains the northwestern corner of the plant and flows northeast through the buffer zone to its offsite confluence with Coal Creek. An east-west trending topographic divide separating the Walnut and Woman Creek drainages bisects the plant. North and South Walnut Creeks and an unnamed tributary drain the northern portion of the plant security area. The Present Landfill is at the head of the unnamed tributary. These three forks of Walnut Creek join in the buffer zone and flow off-site approximately 1 mile east of the confluence.

A number of man-made surface water diversions and storage ponds have been constructed to control surface water discharge from the Plant. As shown in Figure 1-2, there are three series of ponds downstream of the Plant. Ponds on the north fork of Walnut Creek are designated A-1 through A-4. Ponds on the south fork are designated B-1 through B-5. These ponds receive runoff and/or treated sanitary wastewater. Pond C-1 is located on the Woman Creek watercourse. Pond C-2, located near Woman Creek, receives surface runoff water from an interceptor ditch parallel to the south side of the Plant's production areas (Rockwell International 1989b). Discharge from the Plant occurs at seven locations in accordance with a National Pollutant Discharge Elimination System (NPDES) permit (Rockwell International 1989b). The NPDES-permitted outfalls are located at the discharges of Pond B-3 (NPDES No. 001), Pond A-3 (No. 002), Pond A-4 (No. 005), Pond B-5 (No. 006), and Pond C-2 (No. 007). NPDES outfalls Nos. 003 and 004 are located at the Reverse Osmosis Pilot Plant and Reverse Osmosis Plant, respectively.

1.3.3 Surrounding Land Use and Population Density

Approximately 50 percent of the area within 10 miles of the Rocky Flats Plant is in Jefferson County. The remainder is located in Boulder County (40 percent) and Adams County (10 percent). According to the 1973 Colorado Land Use Map, 75 percent of this land at that time was unused or was used for agriculture. Since that time, portions of this land have been converted to residential use, with several new housing subdivisions being started within a few miles of the buffer zone. One such subdivision is located south of the Jefferson County Airport and several are located southeast of the plant (Rockwell International 1989d).

Demographic estimates (Figure 1-5) show that approximately 2 million people lived within 50 miles of the Plant as of 1988 (Rockwell International 1989b), and approximately 10,500 people lived within 5 miles of the plant in 1988. The most populous sector was to the southeast, toward the center of Denver. This sector had a 1988 population of about 630,000 living between 10 and 50 miles from Rocky Flats. Population estimates registered by the Denver Regional Council of Governments (DRCOG) for the 8-county Denver metro region have shown distinct patterns of growth between the first and second halves of the decade. Between 1980 and 1985, the population of the 8-county region increased by 197,890, a 2.4 percent annual growth rate. Between 1985 and 1989, a population gain of 71,575 was recorded, representing a 1.0 percent annual increase. The 1989 population showed an increase of 2,225 (or 0.1 percent) from the same date in 1988 (DRCOG 1989).

There are eight public schools within 6 miles of the Rocky Flats Plant. The nearest educational facility is the Witt Elementary school, which is approximately 2.7 miles east of the plant buffer zone. The closest hospital is Centennial Peaks Hospital located approximately 7 miles northeast.

The closest park and recreational area is Standley Lake, which is approximately 5 miles southeast of the plant. Boating, picnicking, and limited overnight camping are permitted. Several other small parks exist in communities within 10 miles. The closest major park, Golden Gate Canyon State Park, located approximately 15 miles to the southwest, provides 8,400 acres of general camping and outdoor recreation. Other national and state parks are located in the mountains west of the Plant, but all are more than 15 miles away.

Some of the land adjacent to the plant is zoned for industrial development. Industrial facilities within 5 miles include the TOSCO laboratory (a 40-acre site located 2 miles south), the Great Western Inorganics Plant (2 miles south), the Frontier Forest Products yard (2 miles south), the Idealite Lightweight Aggregate Plant (2.4 miles northwest), and the Jefferson County Airport and Industrial Park (990-acre site located 4.8 miles northeast).

Several ranches are located within 10 miles of the plant, primarily in Jefferson and Boulder Counties. They are operated to produce crops, raise beef cattle, supply milk, and breed and train horses.

1.3.4 Ecology

A variety of vegetation is found within the plant boundary. Included are species of flora representative of tall prairie grass, short plains grass, lower mountainous, and foothill ravine regions. Riparian vegetation exists, along the site's watercourses. None of these vegetative species are on the endangered species list (Rockwell International 1989d). Since starting operations at the Plant, vegetative recovery has occurred as evidenced by the presence of grasses like big bluestem and sideoats grama (two disturbance sensitive species).

The animal life inhabiting the Plant and its buffer zone consists of species associated with western prairie regions. The most common large mammal is the mule deer, with an estimated 100 to 125 permanent residents. There are a number of small carnivores, such as the coyote, red fox, striped skunk, and long-tailed weasel. A profusion of small herbivores can be found throughout the plant and buffer zone consisting of species such as the pocket gopher, white-tailed jackrabbit, and the meadow vole (U.S. DOE 1980).

Commonly observed birds include western meadowlarks, horned larks, mourning doves, and vesper sparrow. A variety of ducks, killdeer, and red-winged black birds are seen in areas adjacent to ponds. Mallards and other ducks frequently nest and rear young on several of the ponds. Common birds of prey in the area include marsh hawks, red-tailed hawks, ferruginous hawks, rough-legged hawks, and great horned owls (U.S. DOE 1980).

Bull snakes and rattlesnakes are the most frequently observed reptiles. Eastern yellow-bellied racers have also been seen. The eastern short-horned lizard has been reported on the site, but these and other lizards are not commonly observed. The western painted turtle and the western plains garter snake are found in and around many of the ponds (DOE 1980).

Existing data were compiled to summarize the Present Landfill site's history, physical characteristics, nature of potential contamination, and pathways to human receptors or the environment. The existing data were obtained from a number of previous site investigations as summarized in subsection 2.1.2. The descriptions of physical characteristics and nature of contamination presented in subsections 2.1 and 2.2 were combined to develop a site conceptual model, subsection 2.3.

2.1 PRESENT LANDFILL HISTORY AND PHYSICAL CHARACTERISTICS

Physical characteristics of the region and plant site are presented in subsection 1.3. Details of the Present Landfill site, operations, and landfill structures are presented in this section.

2.1.1 Locations and Histories of SWMUs 114 and 203

2.1.1.1 Present Landfill (SWMU 114)

The following historical perspective of the Present Landfill is based on the 1988 Present Landfill Closure Plan (Rockwell International 1988b).

The Present Landfill is located to the north of the plant security area on the western end of an unnamed tributary of North Walnut Creek. Figure 1-2 shows the general location on the plant property. Operation of the landfill was initiated on August 14, 1968, with a portion of the natural drainage being filled with soils from an onsite borrow area to a depth of up to 5 feet to construct a surface on which to start landfilling.

The landfill was originally constructed to provide a means for disposing of the plant's nonradioactive solid wastes. These wastes included paper, rags, floor sweepings, cartons, mixed garbage and rubbish, demolition material, and miscellaneous items. From 1968 to 1978, the landfill received approximately 20 cubic yards of compacted waste per day (subsection 2.2.1).

To avoid placing radioactive materials in the landfill, the Health Physics unit at Rocky Flats began a program in 1973 to monitor the waste for radioactivity after it had been dumped and before compaction and burial. After radiation monitoring was completed, each waste layer was compacted and covered with 6 inches of soil from onsite stockpiles. The disposal of wastes continued in this manner until the waste layer was within 3 feet of the final elevation. The lift was completed by the addition of a 3-foot-thick layer of compacted soil. In different sections of the landfill, the total landfill thickness consists of between one and three such lifts. Based on visual observation (Rockwell International 1988b), some areas of the landfill surface may not have received a full 3-foot layer of compacted soil.

In September 1973, tritium was detected at the drainage of the landfill. In response, a sampling program was initiated, and two ponds, approximately 1/2-acre each, were formed by constructing temporary berms in the drainage just downstream of the landfill. The purpose of the west pond (Pond No. 1) was to impound leachate generated by the landfill. The east pond (Pond No. 2) was intended as a backup system for any overflow from Pond No. 1. Pond No. 2 was also used to collect intercepted groundwater, as needed.

By 1974, the landfill had expanded in surface area to approximately 300,000 square feet. The volume occupied by the landfill was estimated to be about 95,000 cubic yards. Of this total, the cover material was estimated at 30,000 cubic yards. The remaining 65,000 cubic yards consisted of compacted waste intermixed with the daily cover material placed during disposal.

During 1974 and early 1975, surface water controls and a groundwater diversion and leachate collection system were constructed to address the presence of the apparent tritium source. These systems included an engineered pond embankment to replace the temporary embankment of Pond No. 2, a groundwater interception and diversion system for uncontaminated groundwater, a leachate collection system, and surface water control ditches. The engineered embankment for Pond No. 2 included a low permeability clay core keyed into bedrock. The area of the new pond, now called the east pond, was approximately 2-1/2 acres. The intent of the new structures was to protect surface water and groundwater from contamination by leachate generated in the landfill. Construction of these systems began in October 1974, and was completed in January 1975. Details of these structures are discussed further in subsection 2.1.6 (Plate 2-1 and Figure 2-10).

The collection systems consisted of a surface water interceptor ditch and a combined leachate and groundwater interceptor system. The surface water ditch intercepted surface water runoff flowing toward the landfill and directed it away from the landfill. The leachate collection and groundwater diversion systems were constructed between the surface water interceptor ditch and the landfill to divert groundwater flow around the landfill, to collect leachate generated in the landfill, and to provide additional disposal area. The collected leachate was discharged into the west pond (formerly Pond 1). Discharge of the intercepted groundwater could be directed to the west pond, east pond, or to surface drainages downgradient of the east pond by a series of valves in the subsurface pipes. When disposal continued after 1974, the trench in which this system was constructed was backfilled with waste fill, and the east face of the waste area was advanced to the east.

To keep the ponds from overfilling and discharging into the drainage, water from them was periodically sprayed on the ground surface adjacent to the landfill to enhance evaporation. One of these sprayfields was a 3- to 3-1/2-acre plot, located approximately 1,000 feet northwest of the east pond. This north sprayfield was used for spraying water collected in the west pond. Two other sprayfields were located along the banks of the east pond and were used for spray evaporation of water collected in the east pond. Spraying the east pond banks is still practiced.

Between 1977 and 1981, portions of the leachate and groundwater diversion system were buried during landfill expansion. The eastward expansion covered the discharge points of the leachate collection system into the west pond. The west embankment and pond were covered in May of 1981 during further eastward expansion of the landfill. In addition, two slurry walls were constructed in 1982 to extend the groundwater barriers that were already in place. The slurry walls were intended to reduce groundwater migration into the expanded landfill area. These slurry walls were tied into the north and south arms of the groundwater diversion system.

The landfill volume in 1986 was estimated by using topographical maps and by calculating the volume of the groundwater and leachate collection ditches that had been filled with waste. These calculations showed that approximately 160,000 cubic yards of material had been placed between 1974 and 1986, for a total landfill volume of 255,000 cubic yards. This volume included solid wastes, wastes with hazardous constituents, and soil cover material.

Between 1986 and 1988, waste was disposed of at a rate of 115 cubic yards per work day (Rockwell International 1988b). Using this rate, and then assuming 260 work days per year for 4 years, approximately 120,000 cubic yards of waste material have been disposed of since 1986. Daily cover volumes have been estimated at about 25 percent of the volume of material disposed. Based on these assumptions, the volume of material in the landfill is currently estimated to be approximately 405,000 cubic yards.

2.1.1.2 Inactive Hazardous Waste Storage Area (SWMU 203)

The Inactive Hazardous Waste Storage Area is located on the southwest corner of the Present Landfill (Figure 2-1 and Plate 2-1) and was actively used between 1986 and 1987. The following description of the site and its history is from the 1988 closure plan (Rockwell International 1988c). This area was operated as a hazardous waste storage area for both drummed liquids and solids. Fifty-five-gallon containers with free liquids were stored within 14 cargo containers. One additional container was used to store spill control items such as oil sorbent and sorbent pillows.

Figure 2-1 is a diagram of the hazardous waste storage area as it looked during maximum waste inventory. During maximum inventory, the hazardous waste area consisted of eight 20-foot-long cargo containers each capable of holding eighteen 55-gallon drums, and six 40-foot-long cargo containers each capable of holding forty 55-gallon drums. Fifty-five-gallon drums were placed and conveyed in the cargo containers on rollers constructed of aluminum. Two conveyors extended along the full length of the cargo container. A 3-foot-wide aisle, wide enough to permit access and inspection, extended down the center of the cargo container. The rollers elevated the drums approximately 2 inches above the catch basin floor (Baker 1988).

The cargo containers were modified to meet the requirements for secondary containment under 6 CCR 1007-3 Section 264.175. Containers were fitted with signs, air vents, electrical ground, and locks. A catch basin, constructed of 11-gauge steel with a welded steel rim and a minimum height of 6 inches, was placed within each cargo container to contain spills. The basins, as designed, were capable of containing at least 10 percent of the total volume of hazardous waste. The largest container stored in these cargo containers was 55 gallons. Drummed solids (55-gallon containers) were placed outside the cargo containers.

The 1988 Closure Plan indicated small spills of less than reportable quantities occurred in this area during transfer operations. Total liquid storage capacity for the 14 cargo containers was 21,120 gallons. Maximum inventory recorded for all wastes, including solids, is unknown.

RCRA-listed wastes were stored in 12 of the 14 cargo containers and included solvents, coolants, machining wastes, cuttings, lubricating oils, organics, and acids. Two of the 20-foot-long cargo containers also were used to store polychlorinated biphenyl (PCB)-contaminated soil and debris, as well as PCB-contaminated oil from transformers taken out of service (Baker 1988).

During the first week of May 1987, all cargo containers were hoisted intact onto flatbed trailers and transported to their current outdoor location in the parking lot, immediately west of the perimeter security zone (Baker 1988). The Inactive Hazardous Waste Storage Area has been left vacant.

2.1.2 Previous Investigations

A number of previous investigations have been conducted at the site for the purpose of evaluating physical characteristics and potential contamination. Previous studies that were the primary sources of information for this work plan are listed in subsection 1.2. The majority of the information used in the preparation of this work plan was either developed as part of, or summarized in, the July 1, 1988 Closure Plan (Rockwell International 1988b).

Other studies conducted at the Present Landfill besides those listed in subsection 1.2 include the following, with brief summaries of the results:

- Soil gas survey of methane and hydrogen sulfide on landfill's surface using portable gas chromatography methods (results are Appendix 6 to Rockwell International 1988b) (Appendix A of this work plan). Some low levels of methane were detected, and other unknown compounds were present in the landfill soil gas. In addition, Tracer Research conducted a site-wide soil gas survey in 1986. Another soil gas survey using the Petrex method was initiated in 1987 in the landfill area; however, no data were obtained because the sampling points had been improperly located.

- Geotechnical engineering study for proposed landfill expansion (Lord 1977). The claystone bedrock beneath the landfill was judged adequate to serve as a subsurface hydraulic barrier, and the overburden soils were judged adequate for daily landfill cover (Rockwell International 1988b).

- Geotechnical engineering study for landfill remediation (Zeff et at. 1974). Recommendations were made and plans developed for a groundwater diversion and leachate collection system around the perimeter of the landfill. (Design drawings are included as Appendix 1 to Rockwell International 1988b and are presented as Appendix B to this work plan).

- Geotechnical engineering study for three potential future landfill sites and subsurface exploration at Present Landfill (Woodward-Clevenger 1974). The work included 47 borings with numerous soil and waste samples obtained. The samples were turned over to Rocky Flats (Dow Chemical) for analysis. In addition, 3-inch-diameter slotted plastic casings were inserted in the boreholes to allow water level measurements and leachate sampling. Data from testing on the leachate were the basis for an internal memorandum from F.J. Blaha to T.C. Greengard regarding "Radioactive Sources in Rocky Flats Sanitary Landfill" (Rockwell International 1987c). These data are summarized in subsection 2.2.1.

2.1.3 Geology

The Present Landfill site geology is summarized by the following discussion and by the cross sections presented in Figures 2-2, 2-3, 2-4, and 2-5. A surficial geology map was presented in the hydrogeologic characterization report (Rockwell International 1988d). The cross sections in Figures 2-2 through 2-5 are based on 1986 and 1987 (and some previous) boring data. Boring and well data from 1989 operations are presented in Table 2-1 (EG&G 1990a). Well locations and sections are shown in Plate 2-1. The following geology description is based primarily on the 1988 hydrogeologic characterization report with some details revised by EG&G considering interim results at ongoing geologic site characterizations.

2.1.3.1 Surficial Geology

Quaternary surficial materials in the landfill area consist of the Rocky Flats Alluvium, colluvium, valley fill alluvium, and artificial fill or disturbed ground, which unconformably overlie the bedrock units. In addition, there are a few isolated exposures of cretaceous Arapahoe claystone located along the side slopes of the drainage in which the landfill is located. Rocky Flats Alluvium caps the top of the slopes on the north and south sides of the drainage while colluvium (slope wash) covers the hillsides down to the drainage. Artificial fill or disturbed surficial materials are present within the boundaries of the landfill, along man-made drainage ways surrounding the landfill, and northwest of the landfill. Valley fill alluvium is present along the unnamed tributary channel.

The Rocky Flats Alluvium in the landfill area is described as a generally poorly sorted, unconsolidated deposit of clay, silt, sand, gravel, and cobbles. It ranges between 6 (Well No. 72-87) and 27 feet thick (Well No. 60-87) with an average thickness of approximately 18 feet where undisturbed. Lenses of sand, gravel, and clay within the Rocky Flats Alluvium have been correlated between wells that are close to each other.

Colluvial materials are present on the slopes descending to the drainage in which the landfill is located; however, only Well Nos. 7-86 and 8-86 penetrated colluvium in the vicinity of the landfill. Colluvium consists predominantly of clay with common occurrences of sandy clay and gravel layers.

The most recent deposit in the landfill area is the valley fill alluvium along the unnamed tributary channel. The unconsolidated valley fill consists of poorly sorted sand, gravel, and pebbles in a silty clay matrix. This alluvium is derived from reworked and redeposited older alluvium and bedrock materials. Valley fill thickness ranges from 4 feet (Well No. 5-86) to 8 feet (Well No. 40-87) in the landfill area. The valley fill materials are generally finer-grained downstream of the landfill. Alluvial deposits in Well No. 42-87 are described as predominantly gravel with abundant cobbles and pebbles, whereas Well No. 5-86, farther downgradient of the landfill in the unnamed tributary the landfill is at the head of, encountered predominantly very fine-grained sand and gravels with occasional cobbles.

There are two types of artificial fill in the vicinity of the landfill. The first type is comprised of soil materials. A significant amount of the soil materials were derived from excavations of Church

Ditch located northwest of the landfill. There is also engineered fill comprising the east pond embankment dam across the tributary. The core of the east pond dam was constructed of compacted clay and claystones, with the outer shell being composed of clayey sands, gravels, and cobbles. These materials were obtained from borrow areas.

The second type of artificial fill consists of waste and cover soil materials. This fill is described as a mixture of clay, gravel, coarse sand, asphalt fragments, wire, plastics, surgical gloves, wood particles, and other materials associated with landfilling activities. Thicknesses of this fill material, where drilled, ranged from approximately 1.5 feet to approximately 27 feet in the center of the landfill (Woodward-Clevenger 1974). Based on recent observations of the landfill and considering previous subsurface data, the maximum waste thickness toward the central-east portion of the landfill is estimated to be on the order of 40 to 45 feet. This has not yet been substantiated by boring and/or survey data.

2.1.3.2 Bedrock Geology

The Cretaceous Arapahoe Formation underlies surficial materials in the vicinity of the Present Landfill. Six wells were completed in various zones of the bedrock during the 1986 and 1987 drilling programs. The Arapahoe Formation beneath the landfill consists mostly of claystone with some interbedded channel sandstones and siltstones with a thin isolated claystone layer encountered in Well No. 8-86.

The upper Arapahoe sediments were deposited in a fluvial environment by meandering streams flowing generally west to east off of the ancestral Front Range. The basal sandstones(s) were typically deposited as braided streams. Claystones represent overbank and floodplain deposits (EG&G ongoing investigations). Leaf fossils and black organic matter were encountered within the claystones during drilling at the landfill. Contacts between various lithologies are both gradational and sharp.

Claystone was the most frequently encountered lithology in the Arapahoe Formation immediately below the Quaternary/Cretaceous angular unconformity. Claystones are described as massive and blocky containing occasional thin laminae with interbeds of sandstones and siltstones.

Weathered bedrock was encountered directly beneath surficial materials in all of the monitoring wells and test holes drilled during previous investigations. Weathering penetrates approximately 11 feet into the bedrock at Well Nos. 6-86 and 9-86. Both weathered and unweathered claystone contain horizons of siltstone and very fine sandstone.

Bedrock Well Nos. 8-86, 9-86, and 41-87BR were completed in Arapahoe sandstones. Well Nos. 58-87, 64-87, 70-87, and 72-87 encountered shallow or subcropping bedrock sandstones. These sandstones are generally composed of moderately to well sorted, subrounded to rounded, very fine- to medium-grained quartz sand. Cementation generally increases with depth as weathering decreases. Cementing agents in the bedrock are predominantly argilaceous; however, locally and at shallow depth (up to about 10 feet), calcium carbonate (caliche) can dominate as a cementing agent. Silica cement is a minor constituent in the sandstone. Sandstone thicknesses range from approximately 2.5 feet in Well No. 8-86 to 20 feet in Well No. 41-87. The sandstones in Well Nos. 41-87 and 9-86 are generally homogeneous and contain thin beds and laminae of fine siltstone and claystone. Crossbedding was also noted in Well No. 9-86. Weathered sandstone is lithologically similar to unweathered sandstone.

Siltstones were encountered in the Arapahoe Formation associated with the sandstones as gradational units of silty sandstone or sandy siltstone. Well No. 9-86 encountered relatively homogeneous layers of unweathered siltstone at 89 to 122 feet and again at depths of 139 to 144 feet. Subcropping sandstones were encountered during drilling of Well Nos. 65-87, 72-87, and 70-87. Subcropping sandstones were not fully penetrated during the drilling of Well Nos. 70-87 and 72-87.

Plates 4-3 through 4-6 in the 1988 hydrogeologic characterization report showed estimated areas of subcropping sandstones based on an inferred bedding dip of 7 degrees to the east. However, ongoing site-wide geologic investigations by EG&G indicate the bedding is significantly flatter, on the order of 2 degrees or less. Therefore, further study is necessary to estimate areal extents of subcropping sandstones. This will be done during Phase II RFI/RI activities for the Present Landfill.

2.1.4 Groundwater Hydrology

Groundwater occurs in surficial material (Rocky Flats Alluvium, colluvium, valley fill alluvium, and artificial fill) and in Arapahoe sandstones and claystones at the Present Landfill. These two hydraulically connected flow systems are discussed separately below. This discussion is based on Rockwell International (1988d) and more recent groundwater level data presented in Rockwell International (1989a) and EG&G (1990a).

2.1.4.1 Groundwater System in Surficial Materials

Groundwater is present in surficial materials at the Present Landfill under unconfined conditions. Groundwater recharge occurs as infiltration of incident precipitation and from localized spraying of water from the landfill pond conducted to enhance evaporation. In addition, intermittent recharge occurs as infiltration from ditches and creeks and possibly as seepage from the landfill pond. Discharge from the water table occurs as evapotranspiration and as seepage into the landfill pond, creeks, and springs. Groundwater is also discharged from the surficial groundwater system into the underlying bedrock groundwater system.

The surficial groundwater flow system is dynamic, with relatively large water level changes occurring in response to precipitation events and to stream and ditch flow (Hurr 1976). There are also seasonal variations in the saturated thickness of the surficial materials. In general, water level data for wells completed in Rocky Flats Alluvium, valley fill, and disturbed ground are available starting September 1986 for the 1986 wells and starting between August 1987 and January 1988 for the 1987 wells. Hydrographs showing water surface elevations for the 10 wells on Sections D-D' and E-E' (Figures 2-4 and 2-5) are shown in Figures 2-6, 2-7, and 2-8. These are discussed in subsection 2.1.4.1.1.

A potentiometric surface map based on May 1986 groundwater level data (Figure 2-9) indicates groundwater flow from the landfill is in an easterly direction toward the east pond. The potentiometric surface map also indicates groundwater levels well above pond level on the north, west, and south sides. Therefore, groundwater beneath the hillsides north and south of the pond locally flows toward the pond.

Hydraulic conductivity values were measured in surficial materials from drawdown-recovery tests performed on 1986 wells during the initial site characterization (Rockwell International 1986b) and from slug tests performed on selected 1987 wells. Drawdown-recovery tests were analyzed using the Residual Drawdown Plot (Driscoll 1986) and the method of Bouwer (1978). Slug tests were analyzed by the Bouwer and Rice methods (1976). Results of these tests are summarized in Table 2-2. Test data and analyses are presented in Rockwell International (1988d), which is included as Appendix A to this work plan.

Test results indicate hydraulic conductivity values for the Rocky Flats Alluvium range at Well No. 60-87 from 1.3 x 10^{-3} centimeters per second (cm/s) (1,300 feet per year [ft/yr]) to 1.6 x 10^{-5} cm/s (16 ft/yr) at Well No. 58-87, with a geometric mean of 2.4 x 10^{-4} cm/s (240 ft/yr).

2.1.4.1.1 Impact of Landfill Structures on Alluvial Groundwater. Natural groundwater flow in the vicinity of the Present Landfill is generally eastward through the alluvium following original natural topography toward the center of the drainage. In order to control groundwater flow in and around the landfill, a two-part groundwater diversion and leachate collection system was constructed in 1974. This system was intended to collect and divert groundwater around the outside of the landfill and to collect leachate generated in the landfill and discharge it into the west pond. Details of the design and construction of the system are presented in subsection 2.1.5.

To some extent, the effectiveness of the groundwater diversion and leachate collection system may be judged based on existing water level data. The investigation for the Present Landfill Hydrogeologic Characterization Report (Rockwell International 1988d) included constructing three alluvial monitoring wells along a section just upgradient (west) of the west end of the groundwater diversion and leachate collection system (Section E-E'), and seven alluvial monitoring wells along an approximate north-south section through the approximate center of the landfill (Section D-D'). The locations of these sections are shown in Plate 2-1, and Sections D-D' and E-E' are shown in Figures 2-4 and 2-5, respectively. Water level hydrographs for these 10 wells were previously presented in Figures 2-6, 2-7, and 2-8.

In general, the water level data for Section E-E' (Figure 2-6) indicate the groundwater is drawn down toward the groundwater diversion and leachate collection system. However, water level data are not available on this section just downgradient (east) of the system. Therefore, it can not be determined if the system is collecting and diverting all alluvial groundwater at this location. Similarly, no conclusions can be made about the effectiveness of the leachate collection system at this location.

In general, the groundwater level data from the seven wells along Section D-D' show water levels within the landfill similar to, but somewhat lower than, those outside of the groundwater diversion and leachate collection system. Data for the three wells across the southern landfill boundary (Figure 2-7) indicate apparent cyclic fluctuations of about 10 to 12 feet in the water level just inside the landfill. The water levels in the two wells just outside of the southern landfill boundary were near the water levels north of the north landfill boundary. Rockwell International (1988d) concluded that the lack of groundwater in Well No. 63-87 at the time of the first measurement in 1987 and the fluctuations in water level in Well No. 64-87 may have indicated the groundwater diversion and leachate collection system was functioning intermittently. Subsequent data indicate water levels in Well No. 63-87 are relatively stable and that Well No. 64-87 has undergone a number of significant fluctuations. The fluctuating levels in Well 64-87 may be in direct response to precipitation events. This will be evaluated as part of the Phase I RFI/RI. The original plans for the system indicate maximum water levels in Well No. 64-87 are near the original ground surface elevation in that area. This indicates the potential for groundwater within the landfill to have exited to the south above the top of the clay barrier separating the groundwater diversion component from the leachate collection component of the system (see subsection 2.1.6). There may also be a potential for groundwater inflow to occur into the landfill through alluvial materials beneath the system at the locations shown in Plate 2-1 (see subsection 2.1.6).

In addition to the groundwater diversion and leachate collection system, slurry trenches excavated into rock were constructed on the north and south sides of the east portion of the landfill (see subsection 2.1.6.2 for a more complete description). These slurry trenches were constructed to increase the area surrounded by groundwater controls to allow lateral expansion of the landfill. The purpose of the slurry trenches is to impede the flow of groundwater across them.

The locations of the north and south slurry trenches are shown in Plate 2-1. The well pair 67-87 and 68-87 straddle the north slurry trench. Water levels for well pair 67-87 and 68-87 indicate the water levels are generally within approximately 0.2 to 0.3 foot of each other.

There is not a well pair straddling the south slurry trench. Consequently, evaluation of the effectiveness of the south slurry trench is difficult. Well No. 70-87 was dry January through March 1988, but had a saturated thickness of approximately 7 feet in April 1988 based on water level measurements. Since then, water has been found at varying levels.

2.1.4.2 Groundwater System in Bedrock Materials

Groundwater flow in the Arapahoe Formation occurs within sandstones, siltstones, and claystones. Groundwater recharge to the Arapahoe Formation occurs as infiltration of alluvial groundwater. In general, there appears to be a downward gradient between groundwater in surficial materials and bedrock. This has been demonstrated previously in the bedrock beneath the plant (Hurr 1976 and Rockwell International 1986b, 1988a). Table 2-3 presents vertical hydraulic gradients presented by Rockwell International (1988d) for alluvial/bedrock well pairs 7-86 and 8-86 (bedrock well), 10-86 and 9-86 (bedrock well), and 40-87 and 41-87BR. Calculated vertical gradients range from about 0.2 to 0.5 foot.

Groundwater flow within individual sandstones is from west to east at an average gradient of 0.09 ft/ft based on wells completed in the same sandstones at the 903 Pad and East Trenches Areas (Rockwell International 1987b) and on regional data (Robson et al. 1981a). A site-specific horizontal gradient was not calculated for Arapahoe sandstone (Rockwell International 1988d) because it was not believed that any two wells were completed in a common continuous sandstone at appropriate locations to do so.

Hydraulic conductivity values for Arapahoe sandstones were estimated from drawdown-recovery tests performed in 1986, a slug test performed in 1987, and packer tests performed in 1986 and 1987. Table 2-4 summarizes the results of these tests (Rockwell International 1988d). Hydraulic conductivity values in sandstones from drawdown recovery, slug, and packer tests are in reasonably good agreement, ranging from 4×10^{-8} cm/s to 3×10^{-7} cm/s.

2.1.5 Landfill Area Surface Drainage

The Present Landfill area is drained by an eastward flowing unnamed tributary to North Walnut Creek. The east pond, located immediately downstream of the Present Landfill on the unnamed tributary collects both surface runoff and leachate from the landfill. The unnamed tributary joins North and South Walnut Creek approximately 0.7 mile downstream of the eastern edge of the plant security area before flowing off site.

The surface of the landfill is generally poorly drained. Based on the topography shown in Plate 2-1, the average ground surface slope across the landfill is approximately 1.5 percent down to the east. However, the ground surface is irregular and hummocky, resulting in impeded surface drainage. Standing water collects in many areas during precipitation and snowmelt. Run on to the landfill is controlled by a perimeter interceptor ditch around the north, west, and south sides constructed during the 1974 improvements. This ditch is an approximate 3-foot-deep trapezoidal ditch with a 5-foot bottom width. The north and south branches of this ditch discharge into natural drainage features that drain to points downslope of the east pond embankment.

The landfill pond is recharged by groundwater and surface runoff from the landfill and surrounding slopes to the north and south, which are located upgradient. Water loss from the pond consists of natural evaporation, which is enhanced by spraying water through fog nozzles and spray irrigation over the pond and on the hill to the south of the pond. Seepage through and beneath the pond embankment is presumed to be limited since the embankment contains a clay core keyed into bedrock (see subsection 2.1.5.3). The pond does not directly discharge surface water to the drainage downgradient (Rockwell International 1988b).

2.1.6 Landfill Structures

2.1.6.1 Subsurface Drainage Structures

As discussed in subsection 2.1.1, a subsurface drainage control system was installed around the perimeter of the landfill in 1974 in response to the detection of tritium downstream of the landfill. The system was designed to collect and remove leachate from within the landfill and to intercept and divert uncontaminated groundwater flow around the landfill. The leachate collection system was intended to collect and discharge leachate and lower groundwater levels within the landfill. During subsequent expansion of the landfill in 1981, the groundwater diversion was extended using soil-bentonite slurry walls. The slurry walls were intended to reduce migration of groundwater into the landfill area.

The subsurface drainage system consisted of a combined leachate and groundwater interceptor ditch. The leachate and groundwater collection system components were constructed between the surface water interceptor ditch and the landfill to divert groundwater flow around the landfill, to collect leachate generated in the landfill, and to provide an expanded disposal area. The two-part system was constructed by excavating around the perimeter of the landfilled wastes to depths of 10 to 25 feet. The trench excavation for the system was 24 feet wide at the base, as shown in Figure 2-10 (Rockwell International 1988b). Design drawings are presented in Appendix B to this work plan.

The groundwater collection and diversion portion of the system was installed on the side of the trench away from the landfill waste. This system consisted of a 1-foot-thick sand and gravel blanket installed along the trench face. This blanket drain was designed to intercept groundwater and drain to a 6-inch-diameter perforated pipe installed in the bottom of the trench. The intercepted waters could then be discharged to the west pond, east pond, or to surface drainage downslope of the east pond. Control of discharge was accomplished by a series of valves (Plate 2-1). On top of the sand and gravel blanket, a 10-foot-wide clay barrier was placed, which separated the groundwater collection system from the leachate collection system. The design sections and details indicate the trench and clay barrier to be keyed into bedrock. However, the profile sheets in the same set of plans (sheets 2 and 3 of 12, Sanitary Landfill Renovations, Appendix B) indicate the bottom of the system to be above the bedrock surface at some locations. The locations of these areas are identified in Plate 2-1 as potential breaches beneath the system. The leachate collection system consisted of a 5-foot-thick gravel backfill placed in the bottom of the trench on the landfill side. Collected leachate was discharged into the west pond. The west pond was intended to retain the leachate without discharging to the east pond (Rockwell International 1988b).

Between 1977 and 1981, the leachate collection and groundwater diversion system was buried beneath waste during landfill expansion. Lateral expansion of waste placement has resulted in wastes being located beyond the extent of the subsurface drains (Rockwell International 1988b). Eastward expansion covered the discharge points of the leachate collection system into the west pond.

It is not clear how the groundwater diversion and leachate collection system is functioning. Water level data (subsection 2.1.4.1.1) indicate groundwater outside of the landfill is probably not drawn down toward the system on the north and south sides of the landfill at the location of Section D-D' (Figures 2-4 and 2-8). In addition, water levels within the landfill are relatively high, sometimes higher than those on the outside (Figure 2-8, Well No. 64-87). Considering the poor surface drainage conditions of the landfill, much of the groundwater within the landfill could be from direct vertical infiltration of precipitation and snowmelt. It is not known how much, if any, recharge occurs through or beneath the groundwater diversion system. Leachate drainage from the leachate collection system may be impeded since the discharge points into the west pond have been covered. Covering the discharge points could cause leachate to back up in the drainage system.

2.1.6.2 Slurry Walls

Two soil-bentonite slurry walls were constructed in 1982 to extend the groundwater barriers already in place. The locations of the slurry walls are shown in Plate 2-1. The slurry walls were constructed to reduce groundwater migration from the north and south into the expanded landfill. Design drawings of the construction are presented in Appendix 1 to the 1988 closure plan (Rockwell International 1988b) and are included in Appendix B of this work plan. These slurry walls were tied into the north and south arms of the groundwater diversion system (Plate 2-1). The slurry walls were to tie into the clay barrier constructed in 1974.

The details of the connection in the design drawings indicate the slurry walls extend into the leachate collection system and cut-off the sand drain at the connections. Where the slurry walls intersect the groundwater diversion system at their west ends, the existing perforated pipe was replaced with concrete-encased ductile iron pipe. Therefore, the hydraulic continuity of the sand-gravel drain was interrupted and the only hydraulic connection of the groundwater diversion drain across the slurry trench was through the new segment of pipe. As a result, if these pipes were to be damaged or clogged, there would be no outlet from the groundwater diversion system. The slurry walls extend eastward approximately 700 feet from these points of intersection. Based on design drawings, the slurry walls vary in depth from 10 to 25 feet.

2.1.6.3 East Pond Embankment

In 1974, a new east pond embankment was constructed in approximately the same location as the original dike for Pond No. 2, 1,200 feet east of the 1974 landfill position. The new embankment was an engineered dam structure with a spillway and was designed to retain the majority of the water in the channel. A low permeability clay core keyed into bedrock was constructed within the embankment to reduce seepage through it. The remaining shell of the embankment was constructed of more pervious silty to clayey granular soils.

2.1.6.4 Inactive Hazardous Waste Storage Area

The history and operations of the Inactive Hazardous Waste Storage Area (SWMU No. 203), which is located near the west end of the Present Landfill, are discussed in subsection 2.1.1.2. This area is currently vacant and gravel covered. The ground surface appears flat and nearly level. The location of the Inactive Hazardous Waste Storage Area is shown in Plate 2-1.

2.2 NATURE OF CONTAMINATION

The following summary of the nature of contamination consists of edited excerpts from Rockwell International (1988b, 1988d, 1987c), and EG&G (1990a).

2.2.1 Source

The landfill was designed for disposal of the plant's nonradioactive solid waste, including paper, rags, floor sweepings, cartons, mixed garbage and rubbish, demolition materials, and miscellaneous items. Little testing has been performed to characterize the landfilled wastes. However, in 1986 and 1987, studies were conducted to identify waste streams generated at the Rocky Flats Plant (Rockwell International 1986i, j, k, l). At that time, approximately 1,500 waste streams were identified. At the time of the study, 338 of these waste streams were being sent to the landfill for disposal, which included 241 waste streams identified as nonhazardous solid waste (Table 2-5) and 97 solid waste streams that contained hazardous waste or hazardous constituents (Table 2-6).

The nonhazardous solid waste streams being disposed of in the landfill included office trash, empty cans and containers, used filters, and various electrical components. Also included in this waste stream were dried sanitary sewage sludge placed during the 1970s, solid sump sludge, and other miscellaneous sludges.

The waste streams identified as hazardous fell into four general categories. The first consisted of containers partially filled with paint, solvents, degreasing agents, and foam polymers. The second category was Kimwipes and rags that were contaminated with these materials. Filters were included as the third hazardous waste stream and were typically silicone oil filters, paint filters, oil filters, and other used filters that may have contained hazardous constituents. The fourth category consisted of metal cuttings and shavings, including mineral and asbestos dust, and miscellaneous metal chips coated with hydraulic oil and carbon tetrachloride.

In the fall of 1986, wastes with hazardous constituents ceased to be disposed of in the landfill. This policy was implemented through the tightening of administrative procedures and the implementation of the findings of the Waste Stream Identification and Characterization Reports (Rockwell International 1986i, j, k, l and 1987d).

In September of 1973, tritium and strontium 89, 90 were detected at the drainage of the Rocky Flats sanitary landfill by the Lawrence Livermore Laboratories (Rockwell International 1987c). Because of this finding, monitoring wells (at the time called environmental test holes) were installed in the landfilled waste to try to identify the sources of tritium and strontium 89, 90. From September 1973 to January 1974, the results from strontium 89, 90 analyses showed large variations in concentration. The Lawrence Livermore Laboratories sample that had been thought to be greatly elevated in strontium (34 pCi/l) was reevaluated and found to be less concentrated (16 pCi/l) but still above background levels. Background levels were considered to be approximately 1 to 2.5 pCi/l for strontium 89, 90 in water, based upon water samples taken in that time period from Rock Creek. Samples of groundwater/leachate from boreholes in the landfill were analyzed for strontium 89, 90, and only one sample (from TH-4, Woodward-Clevenger 1974) appeared elevated in strontium 89, 90 at 7 pCi/l. All other samples of groundwater/leachate had strontium 89, 90 concentrations of less than 1 pCi/l. The detection limit of the method used to analyze for strontium 89, 90 at the time was 0.1 pCi/l. Strontium 89, 90 was analyzed in the landfill ponds, drainages, and groundwater intercept system, and generally found at background levels. Table 2-7 presents the strontium 89, 90 results from the landfill ponds in the period from 1973 to 1984. The data did not appear to indicate a problem with migration of strontium (Rockwell International 1987c).

Results for tritium were more consistent. Monitoring wells were installed a number of different times resulting in approximately 57 wells installed directly in the landfilled waste or directly below the saturated waste materials by the end of the investigation. Elevated tritium readings were followed by drilling more borings/wells until the general location of the source of tritium had been fairly well identified (Rockwell International 1987c). The tritium concentrations in the water near the tritium source were as high as 301,609 pCi/l (TH-46). The coordinates of the well from which this highest level reading was obtained were 20,015 feet east and 39,535 feet north (Rocky Flats coordinates). The depth of the tritium source, total activity, configuration, and container, if any, were not determined. It was estimated in 1974 that the waste containing the source was dumped in approximately 1970. The wells near the eastern end of the landfill exhibited decreasing tritium concentrations. Seeps of leachate at the eastern end of the landfill had tritium concentrations of 5,000 to 7,000 pCi/l in 1973/1974.

The leachate and runoff water collected in the western leachate pond were found to contain 1,800 to 7,922 pCi/l of tritium in 1974. The tritium concentrations in this pond decreased with time (922 to 1,365 pCi/l in 1977, and 490 to 886 pCi/l in 1980). Table 2-8 shows the tritium concentrations found in the western pond. The western landfill pond was removed for landfill expansion in May/June of 1981.

To summarize, little is known about the nature of contamination contained within the landfilled wastes. Some data are available on tritium and strontium 89, 90 in the landfill leachate and east and west pond water. The pond data indicate a reduction in radioactive contaminants with time. The only other information available on source characterization is the 1987 and 1988 waste solid and hazardous stream characterizations.

2.2.2 Soils

Data have not been obtained for the purpose of characterizing the nature and extent of contaminated soil around and beneath the landfill nor at the Inactive Hazardous Waste Storage

Area. It may be reasonable to assume that the nature of contamination is similar to the groundwater contamination (see subsection 2.2.3). Since much of the waste volume is saturated, it is likely some soil contamination exists immediately beneath and downgradient of the landfill.

2.2.3 Groundwater

Since little data exist on direct characterization of the soils and source at the Present Landfill, a comparison of upgradient and downgradient groundwater quality data has been used to identify potential contaminants within the landfill. The following summary of groundwater analysis is based on the Draft Background Geochemical Characterization Report for the entire plant site (Rockwell International 1989e); the 1988 Annual RCRA Groundwater Monitoring Report for Regulated Units at Rocky Flats Plant (Rockwell International 1989; Appendix E to this work plan); and the 1989 Annual RCRA Groundwater Monitoring Report for Regulated Units at Rocky Flats Plant (EG&G 1990a; Appendix F to this work plan).

In order to facilitate the interpretation of groundwater contamination at the Present Landfill, a background characterization program was implemented to define the spatial and temporal variability of naturally occurring constituents. Fieldwork was conducted in 1989, and a draft Background Geochemical Characterization Report for the entire Rocky Flats site was prepared by Rockwell International and submitted to the regulatory agencies (Rockwell International 1989e). The document summarized background data for groundwater, surface water, sediments, and geologic materials, and identified preliminary statistical boundaries of background variability. Spatial variations in the chemistry of geologic materials and water were addressed by sampling locations throughout the plant site. The information in the draft background geochemical report (one round of groundwater samples) was used to preliminarily characterize inorganic contamination at the Present Landfill (Table 2-9).

Two alluvial wells (Well Nos. 7-86 and 10-86) and two bedrock wells (Well Nos. 8-86 and 9-86) were installed at the Present Landfill as part of plant-wide hydrogeologic site investigations in 1986. Three additional wells (alluvial Well Nos. 40-87 and 42-87, and bedrock Well No. 41-87BR) were installed in and around the landfill in 1987 according to the CEARP Phase 2 Site Specific Monitoring Plan. Alluvial Well Nos. 58-87, 59-87, 60-87, 61-87, 62-87, 63-87, 64-87, 65-87, 66-87, 67-87, 68-87, 60-87, and 72-87 were also completed in and around the landfill in 1987 to evaluate groundwater quality and the performance of the groundwater diversion system and the slurry wall.

Fifteen additional wells were proposed for the Present Landfill Area in the 1988 Annual RCRA Ground-Water Monitoring Report (Rockwell International 1989a). These wells were proposed to monitor groundwater quality and water levels within the landfill, in sandstone units that subcrop beneath the landfill, and in the weathered claystone. Thirteen wells (B106089, B206189, B206289, B206389, B206489, B206589, B206689, B206789, B207889, B206989, B207089, B207189, and B207289) were actually installed.

Quarterly monitoring of the wells at the landfill was initiated immediately upon their completion and development. The 1986 wells were sampled once during 1986 and quarterly during 1987, 1988, and 1989. The 1987 wells were sampled once during 1987 and quarterly during 1988 and 1989. The 1989 wells were sampled once in late September 1989. (The September 1989 samples for the 1989 wells were considered fourth quarter samples.)

Results of hydrogeologic investigations of the Present Landfill (Rockwell International 1988d) suggest that the groundwater diversion system may not isolate the landfill from the surrounding groundwater. Based on alluvial groundwater quality data from wells within and surrounding the landfill, Rockwell International 1988d states that it appears the landfill contributes calcium, bicarbonate, and to a lesser extent, sodium, sulfate, iron, manganese, and strontium to the groundwater. Groundwater to the north of the north slurry wall had similar concentrations of these analytes, which may be because of the historical spray irrigation operation north and upgradient of this location (EG&G 1990a).

2.2.3.1 Alluvial Groundwater Quality Within the Present Landfill

Groundwater data compared with the draft geochemical background study results (Rockwell International 1989e) show that there are areas of alluvial groundwater at the landfill that appear to have elevated concentrations of 1,1,1-TCA, TCE, barium, calcium, iron, magnesium, manganese, sodium, strontium, zinc, sulfate, chloride, total dissolved solids (TDS), tritium, and uranium. For pre-1989 wells, this assessment is based on second quarter 1989 volatile organics, dissolved metals, and inorganics data, and second quarter radiochemistry data. Fourth quarter 1989 inorganics data, and to a lesser extent, dissolved metals and volatile organics data, exist for the 1989 wells. The fourth quarter 1989 data base is more extensive than for previous sampling events caused by the installation of several 1989 monitoring wells.

Based on inorganic parameters exceeding background levels, groundwater at Well Nos. 63-87, 70-87, 65-87, 72-87, 58-87, 66-87, 67-87, 71-87, B206089, and B206489 indicated contamination by the landfill. Three of these wells are located in the landfilled wastes. Groundwater at all other wells completed in the Rocky Flats Alluvium did not appear contaminated (EG&G 1990a), although it was noted that nitrate occurred slightly above background in many of these wells including the upgradient Well No. 10-86. Iron and manganese concentrations at Well No. 63-87 were on an order of magnitude greater than the proposed concentration limits (5.38 mg/l and 3.9 mg/l, respectively). At both Well Nos. 63-87 and 70-87, strontium (0.67 mg/l, 0.64 mg/l), TDS (597 mg/l, 581 mg/l [second quarter 1988]), and total uranium (6.5 pCi/l, 18.4 pCi/l [second quarter 1988]) exceeded proposed concentration limits.

Although insufficient samples existed for second quarter 1989 radiochemical analysis for Well No. 63-87, and tritium was at background concentrations during the second quarter 1988, tritium concentrations ranged from 1,800 ± 100 to 2,100 ± 100 pCi/l in the first, third, and fourth quarters of 1988, respectively. Zinc and copper exceeded background (background is the proposed concentration limit) in Wells Nos. 58-87 (zinc only), 66-87, 67-87, 70-87, and 72-87.

Typical of most sanitary landfills, the Present Landfill is observed to impact groundwater quality through increased major ion, iron, manganese, and zinc concentrations. Strontium and copper concentrations were also elevated. Atypical of most sanitary landfills, there are areas of elevated uranium and tritium.

Generally, volatile organic contamination is low and sporadic in occurrence. TCE and 1,1,1-TCA were present above detection limits in Well Nos. 65-87 and 66-87 during the second quarter of 1989. The frequent occurrence of these compounds in other quarters suggest TCE and TCA are contaminants in Well No. 66-87, and TCE is a contaminant in Well No. 65-87 (and Well No. 72-87 based on data from previous quarters).

Methylene chloride, toluene, and chloroform were each present in at least one sample from almost every landfill area well in 1988 (including upgradient Well No. 10-86). However, these compounds were also commonly found in the laboratory blanks and were not detected in second quarter 1989 samples from these wells. This suggests these concentrations may have represented laboratory contamination.

2.2.3.2 Downgradient Valley Fill Groundwater Quality

Wells Nos. 7-86, 40-87, 42-87, 6-86, and 5-86 are located progressively downgradient of the Present Landfill and are completed in the valley fill material. Except for dissolved metals and volatile organics data for Well No. 42-87 during second quarter 1988 and 1989, these wells were either dry or insufficient water existed for chemical analysis. The second quarter 1989 dissolved metals and volatile organics data, and the first quarter 1988 inorganic and radionuclide data, indicate groundwater in Well No. 42-87 is not contaminated.

The high concentrations of analytes in Well No. 5-86 during the first quarter 1988 were not characteristic of the groundwater within or immediately downgradient of the landfill (Well No. 42-87), indicating that another source of high TDS water may exist downgradient of the landfill. Since no SWMUs are known to be located downgradient of the landfill, this source may be caused by natural saline mineral dissolution. Because gross alpha (110 pCi/l), total uranium (169 pCi/l), strontium (7.9 mg/l), sulfate (4,125 mg/l), chloride (271 mg/l), and TDS (7,430 mg/l) exceeded the proposed concentration limits at Well No. 5-86, the source of this groundwater will be addressed during Phase II RFI/RI activities.

2.2.3.3 Weathered Claystone Bedrock Groundwater Quality

Well Nos. B206189, B206689, B206789, B206889, B206989, and B207289 were installed in 1989 to monitor groundwater within weathered claystone at the Present Landfill. Fourth quarter 1989 data available for these wells included inorganics data for Well Nos. B206189, B206289, B206689, B206789, and B206989; dissolved metals data for Well Nos. B206189 and B206789; and volatile organics data for Well Nos. B206689, B206889, and B206989. Well No. B207289 was dry.

Chloroform was the only volatile organic compound present above detection limits in groundwater samples from the weathered claystone, it occurred in the sample from Well No. B206889 (7 μg/l). Because chloroform is not an apparent contaminant of alluvial groundwater at the Present Landfill, these data may not have significance with respect to source characterization.

Inorganics were above background levels in all five wells for which inorganics data were available. The proposed concentration limit for TDS (400 mg/l) was exceeded at Well No. B206169 (720 mg/l) and B206789 (1,200 mg/l), and the proposed concentration limit for sulfate (250 mg/l) was also exceeded at Well No. B206789 (590 mg/l). Chloride did not exceed the proposed concentration limit in any well. Nitrate was elevated above background (0.58 mg/l) at Wells Nos. B206669 (1.1 mg/l), B205789 (6.3 mg/l), and B206989 (32 mg/l). As nitrate concentrations in alluvial groundwater within the landfill are generally below 5 mg/l, further sampling and analysis would be required to explain the occurrence of these nitrate levels in weathered bedrock. Nitrate was not elevated in weathered sandstone Well No. B207089 adjacent to Well No. B206989.

Dissolved metals above background in either Well No. B206189 or B206789 included calcium, lithium, manganese, molybdenum, selenium, sodium, strontium, and zinc. Concentrations of these metals notably exceeding background included lithium in Well No. B206789 (0.2 mg/l; background [bkg] 0.005 mg/l) and sodium in both wells (217 and 130 mg/l, respectively; bkg 37 mg/l). Elevated molybdenum had been observed in the alluvial groundwater at Well No. 64-87 (0.355 mg/l) during first quarter 1988, but molybdenum was below background during the subsequent two quarters. Fourth quarter 1989 dissolved metals data have not been received for Well No. 64-87. This information is necessary to better understand the alluvial/bedrock groundwater interaction at this location. Additional groundwater quality data are necessary to determine the significance of the elevated selenium at Well No. B206789, which significantly exceeds the proposed concentration limit of 0.01 mg/l; however, this will be addressed by a Phase II RFI/RI.

2.2.3.4 Weathered Sandstone Bedrock Groundwater Quality

Well Nos. B206589 and B207089 were completed in the weathered sandstone at the Present Landfill. Only fourth quarter 1989 inorganics data are available for these wells. Elevated TDS, sulfate, and chloride occurred in groundwater at both wells. Concentrations were more notable in Well No. B207089 where sulfate (460 mg/l), chloride (520 mg/l), and TDS (1900 mg/l) all exceeded the proposed concentration limit in Well No. B206589 (550 mg/l). Sulfate and TDS in this well were similar in magnitude to the alluvial groundwater in this vicinity (Well No. 72-87); however, chloride was considerably higher in groundwater from the weathered sandstone (57 mg/l) than in the alluvial groundwater (<16 mg/l). The alluvium was dry in the vicinity of Well No. B207089, which did not allow a comparison to be made.

2.2.3.5 Unweathered Sandstone Bedrock Groundwater Quality

Four bedrock wells completed in unweathered sandstone currently exist outside the landfill to monitor bedrock groundwater quality. Well No. 9-86 is located immediately west of the landfill; Well No. 8-86 is located immediately east of the landfill; and Well Nos. 41-87BR and B207189 are downgradient of the landfill embankment in the unnamed tributary on North Walnut Creek. For Well Nos. 9-86, 8-86, and 41-87BR, the following assessment was based on second quarter 1989 volatile organics, dissolved metals, and inorganics data, and first quarter 1989 volatile organics, dissolved metals, and inorganics data. Volatile organics were not detected in any of these wells.

Bedrock groundwater at Well Nos. 41-87 and B207189 was similar in quality and appeared to have elevated concentrations of barium, calcium, magnesium (Well No. 41-87 only), manganese (Well No. 41-87 only), strontium, chloride, and TDS (Well No. 41-87 only), while all groundwater quality at Well No. 8-87 was within the background tolerance intervals. However, the upgradient bedrock groundwater appeared to have elevated concentrations of some of these constituents. Well No. 9-86 had above background concentrations of barium, magnesium, and manganese, suggesting the upper limit background ranges for these compounds was higher than estimated in the background characterization program. The high concentrations of major ions and metals at Well Nos. 41-87 and B207189 were not observed in alluvial groundwater within, adjacent to, or immediately downgradient of the landfill. It may be concluded that the quality of the groundwater in this sandstone, as in the claystone, reflects dissolution of minerals within the sandstone and claystone. The background characterization provides further evidence that, in general, unweathered sandstone groundwater was higher salinity than groundwater in surficial materials. The concentrations of the above cited metals and inorganics are not notably above background levels.

2.2.3.6 Summary of Groundwater Impacts

Based on an examination of alluvial water quality data from wells within the landfill, it appears the landfill is impacting groundwater with major ions, manganese, strontium, iron, tritium, and uranium. High salt concentrations further down the drainage (Well No. 5-86) may result from other unidentified and possibly natural sources such as naturally occurring salts in the upgradient bedrock. Volatile organic contamination appears to occur in some areas of the landfill; however, concentrations are low, and the occurrences are sporadic. Bedrock groundwater quality may be influenced by mineral dissolution within the sandstone and claystone. High salt concentrations observed in bedrock wells are not seen in alluvial groundwater within the landfill.

2.2.4 Surface Water

The following description of surface water quality consists of edited excerpts from the Present Landfill Hydrogeologic Characterization Report (Rockwell International 1988d). The Present Landfill area is drained by an eastwardly flowing unnamed tributary to North Walnut Creek. A landfill retention pond, also known as the east pond, is located immediately downstream of the Present Landfill on the unnamed tributary in which the landfill is located. The pond receives surface and subsurface flow from the landfill. The unnamed tributary joins North and South Walnut Creek approximately 0.7 mile downstream of the eastern edge of the plant security area before flowing off site.

Before it was buried in 1981, leachate and runoff from the landfill entered the west pond upstream of the existing east pond. At that time, the east pond was a backup for overflow from the west pond. Comparison of historical gross alpha, gross beta, tritium, nitrate, pH, total organic carbon (TOC), conductivity, chemical oxygen demand (COD), metals, and TDS data showed the water quality of the west and east ponds to be similar. At times, both gross alpha and gross beta exceeded the water quality criteria in both ponds. Tritium was also elevated at times (on the order of 1,000 pCi/l), which appears to be related to the known tritium source in the landfill. Tritium concentrations in the west pond from 1974 through 1977 were higher than in subsequent years, but they were below the surface water quality criteria. Gross alpha, gross beta, and tritium were lower during the 1986 sampling of the east pond relative to the historical data. There are inadequate data to interpret the significance of this finding; however, in general, there are no levels, moisture content of the wastes, pH, temperature, and waste composition. Some components of landfill-generated gas are methane, hydrogen sulfide, and carbon dioxide. Other gases may also be present as a result of the types of wastes disposed.

A soil-gas survey was conducted at the landfill to evaluate the levels of methane and hydrogen sulfide being generated by the landfill. The results of the survey are presented in an appendix to the Present Landfill Closure Plan (Rockwell International 1988b). The results of the survey did not indicate significant methane or hydrogen sulfide generation by the landfill. However, readings from the portable gas chromatograph used in the survey did indicate the presence of other compounds, which were neither identified nor quantified as part of the survey.

2.3 SITE CONCEPTUAL MODEL

A site conceptual model was developed based on the site physical characteristics and nature of contamination discussed in subsections 2.1 and 2.2. This model is intended to describe known and suspected scores of contamination, types of contamination, affected media, contaminant migration pathways, and environmental receptors. It will be used to assist in identifying sampling needs and potential remedial alternatives.

2.3.1 Sources of Contamination

The primary source of contamination at the Present Landfill is the landfilled wastes. At the Inactive Hazardous Waste Storage Area (SWMU No. 203), the primary source of contamination is potentially contaminated soil near the ground surface. Soils that have been contaminated by leachate from the landfill and sediments deposited by or in contaminated surface water may be considered secondary sources of contamination. Currently, there are not sufficient data to know whether a secondary source of contamination exists. Existing groundwater level data indicate water occurs within the wastes. Therefore, contaminated groundwater within the wastes may also be considered a secondary source of contamination.

2.3.2 Types of Contamination

Little direct characterization of the types of contaminants in the landfill has been conducted to date. Most of what is known is based on waste stream identification studies (see subsection 1.4.3) and groundwater and surface water quality monitoring. As discussed in subsection 2.2, groundwater monitoring has indirectly identified a number of potential contaminants in the landfill. Groundwater at the landfill appears to have elevated concentrations of 1,1,1-TCA, TCE, barium, calcium, iron, magnesium, manganese, sodium, strontium, zinc, sulfate, chloride, TDS, tritium, and uranium. Typical of sanitary landfills, groundwater quality has been impacted through increased major ion, iron, manganese, and zinc concentrations. Elevated uranium and tritium levels also exist in some areas. Soil contamination at SWMU No. 203 has not been characterized.

2.3.3 Release Mechanisms

Contaminants in the landfill may have impacted the soil and bedrock beneath the landfill and the groundwater within and downgradient from the landfill. Groundwater within the landfill has migrated into the pond and potentially into the drainage downstream of it, thereby affecting the quality of surface water and sediment.

The potential generation and/or migration of gases in the landfill could impact air quality. A previous soil-gas survey identified only low concentrations of methane and hydrogen sulfide. However, organic compounds were also detected but not identified or quantified.

The primary mechanism for release of contaminants from the Present Landfill into the affected media is by percolation of groundwater through the wastes and then out of the landfill. Groundwater occurs within the landfill as a result of infiltration of precipitation and also possibly from infiltration of groundwater through or beneath the perimeter groundwater diversion system. Groundwater flow exiting the wastes can then distribute contamination vertically downward and laterally downgradient. Secondary release mechanisms include the runoff of storm water, migration of landfill gases either laterally or to the ground surface, and percolation of groundwater through contaminated soils. The primary mechanisms for release of contaminants from SWMU No. 203 are by percolation into the landfill wastes and by wind dispersal of gases or contaminated dust.

2.3.4 Exposure Pathways

The two primary potential pathways of migration for contaminants related to the primary release mechanisms described above are alluvial and bedrock groundwater flow. The primary exposure pathways to a receptor are, therefore, either by seepage (where groundwater flow intersects the ground surface) or by water supply wells tapping the affected groundwater downgradient of the landfill. Other exposure pathways include wind dispersal of contaminated dust or soil gas, and surface water runoff and sediment transport.

2.3.5 Receptors

Table 2-11 summarizes potential receptors of contaminants via the various exposure pathways described above. For each pathway, there are three potential routes by which contaminants may find their way into a receptor: ingestion, inhalation, and dermal contact.

2.3.6 Summary

The elements of the site conceptual model described above are shown in Figure 2-11. This figure depicts sources of contamination, mechanisms of contaminant release, exposure pathways, and primary receptors. The model as pictured is based on an initial evaluation of preliminary data. As additional information is obtained, the overall model and specific portions of the model, for example, the landfill leachate flow regime, may be refined or expanded to address the issues of concern.

DEVELOPMENT AND SCREENING OF REMEDIAL ALTERNATIVES

This section identifies potential technologies applicable to closure and corrective action at the Present Landfill and the Inactive Hazardous Waste Storage Area. The identified technologies are based on the preliminary site conceptual model developed in Section 2.0. The Phase I RCRA Facility Investigation/Remedial Investigation (RFI/RI) Work Plan is the first step in the evaluation process illustrated in Figure 3-1 and focuses on potentially contaminated soils and source characterization. The Final Phase I RFI/RI Report will include identification and screening of technologies, and assemble an initial screening of alternatives for possible soil/source interim remedial actions.

This section consists of three parts. Subsection 3.1 provides an overview of the Environmental Protection Agency's (EPA) recommended process for developing and screening of remedial alternatives. Subsection 3.2 identifies general response actions applicable to the preliminary site model, and identifies technologies that fall within each general response action. Subsection 3.3 discusses the general data requirements for the general response actions.

3.1 ALTERNATIVES DEVELOPMENT AND SCREENING PROCESS

This section provides a brief overview of the EPA Superfund process that will be employed to develop and evaluate alternatives for Resource Conservation and Recovery Act (RCRA) closure and corrective action for the Present Landfill. The Superfund Comprehensive Environmental Recovery, Compensation and Liability Act of 1980 (CERCLA) process is described in detail in Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (U.S. EPA 1988a), and is substantially identical to that described for RCRA corrective action programs in RCRA Corrective Action Plan (U.S. EPA 1988b). The CERCLA process was adopted because it specifies in the greatest detail the steps that should be followed and because the Interagency Agreement (IAG) requires general compliance with both RCRA and CERCLA guidance.

The steps followed to develop alternatives (Figure 3-1) for the landfill and inactive storage area are discussed below:

- Develop site closure and corrective action objectives based on: chemical- and radionuclide-specific standards (when available); site-specific, risk-related factors; and other criteria as appropriate (for example, RCRA closure performance standards).

- Develop a list of general types of actions appropriate for the landfill and inactive storage area (such as, containment, treatment, and removal) that may be taken to satisfy the objectives defined in the previous step. These general types or classes of action are generally referred to as general response actions in EPA guidance.

- Identify and screen technology groups for each general response action. For example, the general response action of containment for the landfill can be further defined to include the capping and vertical barrier technology groups. Screening should eliminate those groups that are not technically feasible at the site.

- Identify and evaluate technology options for each technology group to select a representative process for each group under consideration. Although specific process options are selected for alternative development and evaluation, these processes are intended to represent the broader range of options within a general technology group. For example, a soil bentonite slurry wall may be selected as representative of vertical barriers and would be used for technical and cost comparisons.

- Assemble the selected representative technologies into site closure and corrective action alternatives for the landfill and inactive storage area that represent a range of treatment and containment combinations, as appropriate.

- Screen the assembled alternatives against the short- and long-term aspects of three broad criteria: effectiveness, implementability, and cost. Because the purpose of the screening evaluation is to reduce the number of alternatives that will undergo a thorough and extensive analysis, alternatives will be evaluated in less detail than subsequent evaluations.

The preceding six steps will be documented in the Present Landfill RFI/RI Reports. The final step, involving a detailed analysis of each alternative, will be performed during the Corrective

Measures Study (CMS). During detailed analysis, each alternative is evaluated against the nine specific evaluation criteria listed below:

- Overall protection of human health and the environment
- Compliance with applicable or relevant and appropriate requirements (ARAR)
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume
- Short-term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance

The above criteria are described in the CERCLA EPA guidance document (1988a). The initial two criteria are considered threshold criteria because these alternatives must be satisfied before further consideration of the remaining criteria. The next five criteria are considered the primary criteria on which the analysis is based. The final two criteria, state and community acceptance, are addressed during the final decision-making process after completion of the CMS.

3.2 IDENTIFICATION OF GENERAL RESPONSE ACTIONS

3.2.1 Listing of General Response Actions

At the Phase I RFI/RI Work Plan stage, the appropriate level of alternatives analysis requires the listing of general response actions most applicable to the type of site under investigation.

General response actions are defined as those broad classes of actions that may satisfy the objectives for remediation and/or closure ultimately defined for the Present Landfill. Table 3-1 provides a list and description of general response actions and typical technologies associated with remediating soils and waste sources. Table 3-1 also includes a general statement regarding the applicability of the general response action to potential exposure pathways.

3.2.2 Application of Response Actions to Potential Exposure Pathways

The response actions outlined in Table 3-1 must be applied to the potential exposure pathways that will be identified for the Present Landfill. The response actions can either be capable of providing control over all or some of the potential pathways. Partially effective response actions can be combined to form complementary sets of response actions that provide control over all pathways.

In general terms, potential human exposure may be avoided by prevention of contaminant release, transport, and/or contact. Thus, application of the response actions may be considered at three different points in each potential exposure pathway: 1) at the point where the contaminant could be released from the source, 2) in the transport medium, and 3) at the point where the contact with the released contaminant could be prevented.

3.2.3 Identification of Technologies

Multiple remedial technologies exist for each general response action. Figure 3-2 identifies and provides brief descriptions of remedial technologies for the general response actions identified in Table 3-1. Technologies listed range from those that are commonplace (such as, capping) to those that are experimental (for example, in situ vitrification).

3.3 DATA NEEDS FOR REMEDIAL ALTERNATIVES EVALUATION

While the identification of general response actions was discussed in the previous section, the selection of the most appropriate action or combination of actions is not warranted at this time. Site and contaminant data are not sufficient to initiate the screening process. The IAG schedule indicates the following data requirements for the Phase I RFI/RI effort are needed for the characterization of the source and soil contaminants and for the preliminary screening of alternatives:

- Source characterization
  - Suite of radionuclide analyses on soil, leachate, and soil gas
  - Suite of organic and inorganic analyses on soil, leachate, and soil gas

- Site physical characterization
  - Groundwater flow regime and surface water/groundwater interaction
  - Soil and rock types and general engineering properties
  - Depth to bedrock
  - Depth to groundwater
  - Soil organic matter

These data will provide for a thorough comparative evaluation of the technologies with respect to implementability, effectiveness, and cost, and will allow for informed decisions to be made with respect to the selection of preferred technologies. The Field Sampling Plan (Section 7.0) reflects the first iteration of collecting the required information.

4.0
APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Section 121(d) of the Comprehensive Environmental Resource, Compensation and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), requires that Fund-financed, enforcement, and federal facility remedial actions comply with applicable or relevant and appropriate requirement (ARAR) federal laws, or more stringent promulgated state laws.

ARARs are being developed on a site-wide basis. Potential ARARs for groundwater have been developed on a preliminary basis for OU No. 2. ARARs for all media will be further developed in the near future, pursuant to the Inter-Agency Ageement (IAG), as a separate document.

5.0 PHASE I RFI/RI WORK PLAN DATA NEEDS AND DATA QUALITY OBJECTIVES

The primary objective of this RCRA Facility Investigation/Remedial Investigation (RFI/RI) will be to collect the data necessary to characterize the soil and potential contaminant source at the Present Landfill and the Inactive Hazardous Waste Storage Area. The data collected during the RFI/RI will also support the evaluation of remedial alternatives (U.S. EPA 1988a). The following are five general goals of an RFI/RI:

- Characterize site physical features
- Define contaminant sources
- Determine the nature and extent of contamination
- Describe contaminant fate and transport
- Provide a baseline risk assessment

Data quality objectives (DQO) are qualitative and quantitative objectives that describe the quality and quantity of data required by the RFI/RI (U.S. EPA 1987). Through application of the DQO process, site-specific RFI/RI goals are established, and data needs are identified for achieving those goals. This section of the RFI/RI Work Plan identifies the Phase I data needs to meet the stated objectives. For this RFI/RI, the objectives are to characterize soils and site physical features, and contaminant sources and nature of contamination in soil and landfill leachate. Contaminant fate and transport, extent of contamination in all media, and final baseline risk assessment will be completed during subsequent phases of this RFI/RI. These RI tasks, however, are being considered and a preliminary baseline risk assessment will be conducted during Phase I.

5.1 EVALUATION OF EXISTING SITE DATA

Existing data indicate:

- Water (leachate) occurs within the landfill waste.

- The water within the landfill is from infiltration of groundwater into the landfill and/or percolation of surface water through the waste.

- Migration of groundwater from the landfill may have resulted in contaminated soils beneath and possibly downgradient of the landfill.

- Soils at the Inactive Hazardous Waste Storage area may be contaminated with organics, metals, and radionuclides. At present, the contamination is believed to be confined to the surface; further delineation of the extent is needed.

- Some organic, metal, and radionuclide contaminants have been identified in groundwater from wells adjacent to the landfill. Data on the contaminants present in the landfill and associated soils is incomplete.

5.2 SITE-SPECIFIC PHASE I RFI/RI OBJECTIVES AND DATA NEEDS

Based on existing data and the conceptual site model, the site-specific Phase I RFI/RI objectives and data needs associated with identifying contaminant sources are shown in Table 5-1. The specific plans and rationale for obtaining the needed data are presented in the Field Sampling Plan, Section 7.0.

The highest quality data possible consistent with Table 5-1 will be collected by following the Rocky Flats Plant Environmental Restoration (ER) Program Standard Operating Procedures (SOP) and through adherence to the Rocky Flats Plant ER Program Quality Assurance/Quality Control (QA/QC) Plan. Organic and metal analyses will be performed using Contract Laboratory Program (CLP) routine analytical services (RAS), and other analyses (radionuclides and inorganics) will be performed in accordance with the QA Project Plan (QAPP).

6.1 TASK 1 - PROJECT PLANNING

The project planning task includes all efforts required to initiate this Phase I RCRA Facility Investigation/Remedial Investigation (RFI/RI) for the Present Landfill and the Inactive Hazardous Waste Storage Area. Activities undertaken for this project have included a compilation of previous site investigation results and the scoping of the Phase I RFI/RI. Results of these activities are presented in Sections 1.0 and 2.0.

Two project planning documents, including this work plan, have been prepared that pertain to this Phase I RFI/RI as required by the draft Inter-Agency Agreement (IAG) among the Department of Energy (DOE), Environmental Protection Agency (EPA), and Colorado Department of Health (CDH). A Field Sampling Plan (FSP) is included in this document, which presents the locations, media, and frequency of sampling efforts. The second document required by the IAG is a Sampling and Analysis Plan (SAP). Included in the SAP are a Quality Assurance Project Plan (QAPP) and Standard Operating Procedures (SOP) for all field activities. The QAPP and SOPs are being revised and will be submitted in July 1990 in accordance with the draft IAG.

6.2 TASK 2 - COMMUNITY RELATIONS

In accordance with the draft IAG, the Communications Department at Rocky Flats is developing a Community Relations Plan to actively involve the public in the decision-making process as it relates to environmental restoration activities. A work plan has been completed and forwarded to EPA, CDH, and the public for review. The work plan specifies activities designed to complete the Community Relations Plan, including plans for community interviews. The draft Community Survey Plan was completed in January 1990, and the draft Community Relations Plan will be completed in September 1990 in accordance with the draft IAG schedules.

The Communications Department also is continuing other public information efforts to keep the public informed of environmental restoration activities and other issues that relate to Plant operations. A Speakers Bureau program sends speakers to civic groups and educational organizations, while a public tour program allows the public to visit Rocky Flats. An Outreach Program also is in place where plant officials will visit elected officials, the news media, and business and civic organizations to further discuss issues related to the Rocky Flats Plant. The Communications Department also receives numerous public inquiries that are answered during telephone conversations or by sending written, informational material to the requestor.

6.3 TASK 3 - FIELD INVESTIGATION

The Phase I RFI/RI field investigation is designed to meet the objectives outlined in Section 5.0. The following activities will be performed as part of the field investigation as described in detail in Section 7.0:

- Drill and sample soils and wastes within Solid Waste Management Units (SWMU)

- Sample surficial soils for organic, inorganic, and radionuclide contaminants (SWMU 203)

- Install monitoring wells in the landfill

- Collect and analyze groundwater samples from existing upgradient and downgradient wells

- Collect and analyze landfill leachate and soil gas samples from new wells and from three surface water stations

- Collect sediment samples

Sample locations, frequency, and analyses are presented in the Field Sampling Plan (Section 7.0). All field activities will be performed in accordance with the Rocky Flats Plant Environmental Restoration (ER) Program SOP unless otherwise noted in the FSP.

6.4 TASK 4 - SAMPLE ANALYSIS AND DATA VALIDATION

Analytical methods for chemical analyses are provided in the ER Program QAPP (Rockwell International 1989d). Analytical detection limits, sample container and volume requirements, preservation requirements, and sample holding times are discussed in subsection 7.2 of the FSP.

Results of data review and validation activities will be documented in data validation reports. EPA data validation functional guidelines will be used for validating organic and inorganic (metals) data (U.S. EPA 1988c). Validation methods for radiochemistry and major ions data have not been published by the EPA; however, data and documentation requirements have been developed by ER Program QA staff. Data validation methods for these data are derived from these requirements. Details of the data validation process are described in the QAPP (Rockwell International 1989d).

6.5 TASK 5 - DATA EVALUATION

Data collected during the Phase I RFI/RI, as well as previous data, will be incorporated into the existing data base and used to better define soil and contaminant source characteristics. These results also will be used in delineating the requirements for the Phase II RFI/RI plans for determining the nature and extent of contamination, and to support the evaluation of proposed remedial alternatives and baseline risk assessment.

6.5.1 Site Characterization

The additional physical data collected during Phase I will be incorporated into existing site characterization. Subsurface data will be used to describe the stratigraphy and geotechnical engineering properties of surficial materials within source areas. A site geologic map and geologic cross sections will be prepared. Groundwater level data will be used to characterize the alluvial groundwater flow regime. This will include leachate flow within the wastes and the influence of the groundwater diversion system on groundwater flow. The response of water levels to precipitation events will be evaluated for both previous and new data. Well hydrographs will be prepared for all wells and the data summarized graphically for wells along the longitudinal and transverse sections through the landfill. Groundwater potentiometric surface maps will also be prepared for different times.

6.5.2 Source Characterization

Analytical data from source boreholes, landfill leachate, and soil samples will be used to:

- Characterize the nature of source contaminants

- Characterize the lateral and vertical extent of source contaminants (within the limitations of the Phase I scope)

- Evaluate onsite contaminant concentrations

Analytical data from soil, sediment, landfill leachate, and groundwater will be used to characterize the nature of contamination. Evaluation of data will include comparison of all available groundwater quality data from upgradient wells with data from downgradient wells in the vicinity of the landfill. This will include checking the validity of previous data, including well construction documentation. It will also require establishing contaminant background levels for the vicinity of the landfill. Data will be summarized graphically and/or in tabular form to assist interpretation. If appropriate, contaminant isopleth maps will be prepared for summary of soil and source contaminants.

The criteria for the identification of contamination will be analyte specific. For volatile organic compounds, any detectable concentrations in samples that are not attributable to laboratory contamination will be considered likely evidence of contamination. For inorganic compounds (including radionuclides), only those concentrations that exceed expected concentrations in background will constitute evidence of contamination. The statistical techniques that will be used to compare concentrations of inorganic compounds collected as part of the Phase I RFI/RI to background concentrations are documented in the Background Geochemical Characterization Report (Rockwell International 1989c). Essential to the implementation of these statistical techniques for groundwater and borehole samples is the classification of each analytical datum by an appropriate geologic unit (such as the Rocky Flats Alluvium, colluvium, or artificial fill [waste]).

6.5.3 Evaluation of Proposed Remedial Alternatives

The preliminary evaluation of proposed remedial alternatives will be based on the information derived for the purpose of site characterization and soil and source characterization. Geotechnical and groundwater flow data from source boreholes will be used to screen general response actions (subsection 3.2).

6.6 TASK 6 - BASELINE RISK ASSESSMENT

A preliminary baseline risk assessment will be prepared for the Inactive Hazardous Waste Storage Area and the Present Landfill as part of the Phase I RFI/RI to evaluate the potential threat to the public health and the environment in the absence of remedial action. Assumptions will be required concerning the extent of contamination and groundwater flow regime. The preliminary baseline risk assessment will evaluate whether or not remedial action appears to be necessary and serves as the justification for performing remedial action (EPA 1989a). Baseline risk assessment will continue during Phase II RFI/RI activities. The risk assessment based on Phase I level data is being initiated by implementation of the Phase I Work Plan. Each of the Phase I sampling activities is designed to begin providing the data needed to complete a baseline risk assessment.

Several objectives will be accomplished under the risk assessment task including identification and characterization of the following (EPA 1989a):

- Toxicity and levels of hazardous substances present in relevant media (for example, air, groundwater, soil, surface water, sediment, and biota).

- Environmental fate and transport mechanisms within specific environmental media such as physical, chemical, and biological degradation processes and hydrogeological conditions.

- Potential human and environmental receptors.

- Potential exposure routes and extent of actual or expected exposure.

- Extent of expected impact or threat; and the likelihood of such impact or threat occurring (such as risk characterization).

- Level(s) of uncertainty associated with the above.

The public health risk assessment and the environmental evaluation will be performed in accordance with EPA and other guidance documents listed in Table 6-1. The risk assessment will address the potential public health and environmental impacts associated with the site under the no action alternative (no remedial action taken). This assessment will aid in the selection of site remedies based on the contaminants of concern and the environmental media associated with potential risks to public health and the environment.

6.6.1 Public Health Evaluation

The risk assessment process is divided into four tasks (EPA 1989a), including:

- Contaminant identification
- Exposure assessment
- Toxicity assessment
- Risk characterization

The task objectives and descriptions of work for each task are described below.

6.6.1.1 Contaminant Identification

The objective of contaminant identification is to screen the information that is available on hazardous substances or wastes present at the site and to identify contaminants of concern to focus subsequent efforts in the risk assessment process. Previous work characterizing aspects of the Rocky Flats Plant and the surrounding area has been done. Additional sampling and analysis of various media will take place in order to support the human health risk assessment, the ecological assessment, and to characterize the site. For this risk assessment, all of the Target Compound List

(TCL) and Target Analyte List (TAL) contaminants at the two OU No. 3 sites will be considered unless the following criteria are met for their deletion:

- Determination that a chemical has not been detected above risk based detection limits
- Environmental fate information that shows that exposure will not occur
- A low frequency of occurrence (less than 10 percent) in environmental media

All chemicals that are deleted and the rationale for their deletion will be discussed in the completed risk assessment.

6.6.1.2 Exposure Assessment

The objectives of the exposure assessment are to identify actual or potential exposure pathways, to characterize potentially exposed populations, and to determine the extent of exposure. An exposure pathway is comprised of four elements:

1. A source and mechanism of chemical release to the environment.

2. An environmental transport medium (for example, air or groundwater) for the released contaminant.

3. A point of potential contact of humans or biota with the affected medium (the exposure point).

4. An exposure route (such as inhalation of contaminated dust) at the exposure point.

The exposure assessment process will include the following actions:

- Analyze the probable fate and transport of compounds for both the present and future uses

- Identify the human populations in the area, typical activities that would influence exposure, and sensitive population subgroups

- Identify potential exposure pathways under current and future land use conditions

- Develop exposure scenarios for each identified pathway and select those scenarios that are plausible

- Identify scenarios assuming both existing and potential future uses

- Identify the exposure parameters to be used in assessing the risk for all scenarios

- Develop an estimate of the expected exposure levels from the potential release of contaminants

Appropriate exposure scenarios will be identified for the site. Scenarios that could potentially be considered include residential, commercial/industrial, and/or recreational. Factors to be examined in the pathway and receptor identification process will include:

- Location of contaminant source
- Local topography
- Local meteorological data
- Local geohydrology/surface water hydrology
- Surrounding land use
- Local water use
- Prediction of contaminant migration
- Persistence and mobility of migrating contaminants

For each migration pathway and for current and future conditions, receptors will be identified and characterized. Potential receptors will be defined by the appropriate exposure scenarios.

6.6.1.3 <u>Toxicity Assessment</u>

In accordance with EPA's risk assessment guidelines, the projected concentrations of indicator chemicals at exposure points will be compared with applicable or relevant and appropriate requirements (ARAR) to judge the degree and extent of risk to public health and the environment (including plants, animals, and ecosystems). Because many ARARs do not exist for certain media (such as soils) nor are all ARARs necessarily health based, this comparison is not sufficient in itself to satisfy the requirements of the risk assessment process. Moreover, receptors may be exposed to contaminants from more than one medium. Nevertheless, the comparison with standards and criteria is useful in defining the exceedance of institutional requirements. The following criteria will be examined:

- Drinking water health advisories
- Ambient water quality criteria for protection of human health
- Center for Disease Control and Agency for Toxic Substances and Disease Registry Soil Advisories
- National Ambient Air Quality Standards

Critical toxicity values (such as numerical values derived from dose-response information for individual compounds) will be used in conjunction with the intake determinations to characterize risk. Toxicity reference values from EPA's Integrated Risk Information System (IRIS) will be preferred to other EPA reference values.

The baseline risk assessment also will include a summary of any toxicological studies performed for chemicals of concern. The quality of these studies and their usefulness in estimating human health risks will be described. A more detailed explanation of the toxic effect of target chemicals will be provided in the appendixes to the human health risk assessment and the environmental evaluation. Toxicity reference values will also be summarized.

For the human health risk assessment, this will include a brief description of the studies upon which selected reference values were based, the uncertainty factors used to calculate the risk reference dose, and the EPA weight-of-evidence classification for carcinogens. For those chemicals without EPA toxicity reference values, a literature search, including computer data bases, will be conducted for selected compounds. A toxicity value will then, if possible, be derived from this information. EPA will be consulted regarding the appropriateness of the data and the methodologies to be used in deriving reference values. Uncertainties regarding the toxicity assessment will be discussed.

Two types of critical toxicity values will be used:

- The risk reference dose
- Slope factor (for carcinogenic chemicals only)

6.6.1.4 Risk Characterization

Risk characterization involves integrating exposure assumptions and toxicity information to quantitatively estimate the risk of adverse health effects. Risk characterization will be performed in accordance with EPA guidance, and a quantitative risk estimate will be performed for all chemicals. To assess the potential adverse health effects associated with access to the site, the potential level of human exposure to the selected chemicals must be determined. Intakes of exposed populations will be calculated separately for all appropriate pathways of exposure to chemicals. Then, for each population-at-risk, the total intake by each route of exposure will be calculated by adding the intakes from each pathway. Total oral, inhalation, and dermal exposures will be estimated separately. Because short-term (subchronic) exposures to relatively high concentrations of chemicals may cause different noncarcinogenic effects than those caused by long-term (chronic) exposures to lower concentrations, two intake levels will be calculated for noncarcinogens for each route of exposure to each chemical, that is, a subchronic daily intake (SDI) and a chronic daily intake (CDI). CDIs will be used for exposure to carcinogens. A reasonable maximum estimate (RME) of exposure based on the 95 percent upper confidence limit of the exposure data will be used where applicable. Risk will be quantified by comparison of contaminant intakes of exposure points to quantitative criteria for protection of human health.

An uncertainty analysis will be performed to identify and evaluate nonsite- and site-specific factors that may produce uncertainty in the risk assessment, such as assumptions inherent in the development of toxicological endpoints (potency factors, reference doses). Moreover, site-specific factors that may produce uncertainty will also be discussed.

The results of the baseline risk assessment will be used to define and evaluate the remedial alternatives during the Feasibility Study (FS).

6.7 TASK 7 - ENVIRONMENTAL EVALUATION

The objective of the environmental evaluation for the Inactive Hazardous Waste Storage Area and the Present Landfill will be to evaluate whether or not the contaminants have caused or are causing any adverse environmental impact. The data to be collected will be used in conjunction with existing data to determine the bioavailability and toxicity of the contaminants to the flora and fauna in the area of the Present Landfill.

The environmental evaluation will be conducted per guidance provided in the "Risk Assessment Guidance for Superfund", Volume II, Environmental Evaluation Manual (EPA 1989d). As with the baseline risk assessment, a preliminary environmental evaluation will be conducted during the Phase I RFI/RI and will be continued into Phase II. The environmental evaluation will include the collection of vegetation, small mammals, arthropods, and aquatic life for determining if bio-accumulation is occurring. The radioecology study (Rocky Flats Plant Radioecology and Airborne Pathway Summary Report) (Rockwell International 1986h), the Final Environmental Impact Statement (DOE 1980), the soils and surface water chemical data, and biological parameters collected during this environmental evaluation will be used to assess both the current and future ecological impacts.

Field and laboratory activities will be necessary to determine what effect contaminants at the Present Landfill are having on the area's flora and fauna. These activities may include field assessments, toxicity testing, and biomarkers.

Aquatic and terrestrial field surveys will provide detailed assessments of ecological effects. A field survey for aquatic invertebrates in the east pond and downstream drainage will be conducted in order to determine if these organisms have been adversely affected by contaminants at this site. The survey will include relative abundance, species richness, community organization, and biomass.

Toxicity tests will be conducted for the aquatic systems if the aquatic survey indicates an impact. The toxicity of environmental media can be estimated using two approaches: a chemistry-based approach or toxicity-based approach. The chemistry-based approach will first be applied where chemical analyses of water, air, soil, or sediment will be compared to published criteria to estimate toxicity. If this analysis fails to explain the contaminant impact on the biota, the toxicity-based approach will be used. The toxicity-based approach involves the measurements of a biological effect associated with exposure to complex mixtures. For this study, toxicity testing will include acute and chronic toxicity methods for aqueous samples.

The concept of biomarkers is that selected endpoints (such as population-ecosystem density, diversity, or nutrient cycling), which are measured in individual organisms, are typically comprised of biochemical or physiological responses that can provide sensitive indices of exposure or sublethal stress. The most direct biomarker to assess exposure is to measure tissue residues, which is a key component of bio-accumulation. Biomarkers for sublethal stress include histopathology, determination of skeletal abnormalities, measurement of gas exchange in plants, and various other measurements (for example, enzymes).

For this evaluation, toxicological endpoints for indicator or target species will be chosen based on a review of available laboratory toxicity tests providing quantitative data for species of concern, when available. In the absence of toxicological indices for the target species, toxicological endpoints will be derived using safety factors that reflect interspecies extrapolation, acute-to-chronic extrapolations, and added protection for endangered and/or threatened species. Procedures to be used for the field and laboratory activities are presented in the "Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference" (U.S. EPA 1989c).

In presenting the conclusions of the environmental evaluation for the two OU No. 3 sites, the degree of success in meeting the overall objective of the evaluation will be discussed. Each conclusion will be presented along with items of evidence that would support or fail to support the conclusions and the uncertainty accompanying that conclusion. Any factors that limited or prevented development of definitive conclusions will also be described. Information will be provided to indicate the degree of confidence in the data that was used to assess the site and its contaminants.

6.8 TASK 8 - TREATABILITY STUDIES/PILOT TESTING

This task includes efforts to prepare and conduct pilot and bench-scale treatability studies and/or review data from recently conducted testing. These activities will serve to determine the operability, reliability, cost-effectiveness, and overall implementability of a particular remedial alternative. The development of treatability studies is being considered on a site-wide basis. Any of these studies specific to OU 3 and SWMUs 114 and 203 will be identified after completion of the Phase I RFI/RI.

6.9 TASK 9 - RFI/RI REPORT

A Draft Phase I RFI/RI Report will be prepared to consolidate and summarize the data obtained during the Phase I fieldwork. This report will provide the following:

- Describe the field activities that serve as a basis for the report. This information will include any deviations from the work plan that occurred during implementation of the field investigation.

- Discuss site physical conditions based on existing data and data derived during the RI. This discussion will include surface features, climate, surface water hydrology, surficial geology, groundwater hydrology, demography and land use, and ecology.

- Present site characterization results discussing the nature and extent of contamination. The media to be addressed will be limited to contaminant source and soils.

Before submission of the Phase I RFI/RI Report, a Preliminary Site Characterization Summary will be submitted for review by EPA and CDH. This summary will provide an early description of the initial site characterization effort including a preliminary presentation of analytical data, and a listing of chemical and radiological contaminants, the affected media, and chemical-specific ARARs.

In addition to the characterization summary, technical memorandums will be prepared with the completion of each field sampling task to provide preliminary results of field investigations.

6.10 SCHEDULE

The schedule for conducting the Phase I RFI/RI is summarized in Figure 6-1. Dates are not shown; however, at the time of the work plan preparation, this schedule was in general conformance with the IAG schedule.

The schedule indicates surface water and well sampling beyond the end of the field activities. This is due to the fact that sampling and analysis is likely to be conducted as part of site-wide activities after the first or second round. They are shown in this schedule to indicate that sampling at the Present Landfill needs to satisfy the Present Landfill Field Sampling Plan, and to show that data evaluation for the Present Landfill RFI/RI should include at least four rounds of sampling.

7.0
FIELD SAMPLING PLAN

The primary objective of the Phase I RCRA Facility Investigation/Remedial Investigation (RFI/RI) will be to collect the data necessary to characterize the soil and contaminant sources at the Present Landfill and Inactive Hazardous Waste Storage Area. Although Phase I of the RFI/RI process specifically does not address the nature and extent of groundwater contamination, it will use leachate and groundwater quality data as a means of evaluating the soils and sources. A secondary objective will be to obtain more information on subsurface physical characteristics, such as the groundwater flow regime within the landfill, to assist in preliminary identification and evaluation of remedial alternatives, and for use in performing a baseline risk assessment. Within these broad objectives, site-specific data objectives and needs have been identified in Section 5.0. The purpose of this Field Sampling Plan (FSP) is to provide a detailed plan for implementing these data objectives and needs of this Phase I RFI/RI.

The sampling activities at each of the two Solid Waste Management Units (SWMU) are outlined below and discussed in detail in subsection 7.1.

- Present Landfill (SWMU 114)
  - Borings
    1. Fifteen locations; 13 with continuous soil sampling for analytical testing, 2 with drive samples every 5 feet for soil classification only
  - Groundwater/leachate monitoring wells at 10 of the 15 boring locations
    1. Thirteen wells: 7 single, 3 pairs
    2. Two piezometers for water level measurements only
  - Sediments
    1. Three locations in the east pond
  - Leachate
    1. Seepage at east toe of landfill (1 location)
    2. Groundwater diversion system discharge points (2 locations)

- Inactive Hazardous Waste Storage Area (SWMU 203)
    - Scoping Surveys
        1. Visual inspection
        2. Radiological field screening
        3. Organic vapor field screening

    - Surficial Soil Sampling and Analysis
        1. Eighteen locations

The RFI/RI process is an iterative one, with Phase I activities intended to identify and quantify the source and soil characteristics. As discussed in subsection 1.2, the Phase I RFI/RI will involve detailed sampling and analysis to characterize the source and soils at a Phase I level. This level of information is not necessarily sufficient for alternatives analysis or to support the no action alternative. Phase II will concentrate on characterization of groundwater, extent of contamination, evaluation of remedial alternatives, and, if necessary, further source and soil characterization.

All sampling and analysis activities will be conducted according to the project Health and Safety Plan (HSP) and the Sample Analysis Plan (SAP). The SAP will include the Standard Operating Procedures (SOP) and the Quality Assurance Project Plan (QAPP), which were being developed at the time of this work plan.

7.1 FIELD SAMPLING

7.1.1 Background

As presented in subsection 2.3, Site Conceptual Model, the primary source of contamination at the Present Landfill is the landfill wastes. A potential secondary source may consist of soils that have been contaminated by leachate beneath or downgradient from the wastes. Existing data indicate that groundwater (leachate) occurs within the wastes. The total thickness of the wastes is nil at the west end and along the north and south edges, and is deeper toward the central east portion of the landfill. Although current topographic information is not available, it is estimated that the maximum thickness of waste is on the order of 40 to 45 feet. The saturated thickness of waste varies from nil at the west end to an estimated 20 feet near the east end. It is possible that some leachate drains through the groundwater diversion system.

In general, groundwater level data indicate that the groundwater diversion system does not function effectively (Rockwell International 1988d). As discussed in subsection 2.1.6.1, it is possible that this system was not keyed into the bedrock in some areas. Those locations are identified in Plates 2-1 and 7-1. Recharge to the groundwater within the landfill occurs as a result of infiltration of precipitation directly into the landfill and also possibly from infiltration of groundwater through or beneath the perimeter groundwater diversion system. As indicated in Figure 2-9, the direction of groundwater flow is probably in general accordance with the large-scale slope of the original ground surface in this vicinity. The overall horizontal groundwater gradient is to the east, averaging about 4 percent from near the west end of the landfill to the east pond.

In the landfill area, the waste materials overlie a relatively thin layer of surficial soils, generally 10 feet or less, which in turn overlie weathered bedrock. In the western portion of the landfill, where operations started in the late 1960s, a layer of soil fill, up to 5 feet thick, was reportedly placed in the valley bottom before placement of waste. It is not known whether this type of subgrade preparation was conducted for subsequent expansion to the east.

The Inactive Hazardous Waste Storage Area (SWMU 203) is a nearly level gravel-covered vacant area near the west end of the Present Landfill. This area was operated as a hazardous waste storage area that consisted of drums contained within cargo containers. Site reconnaissance conducted for the 1988 closure plan (Rockwell International 1988c) did not identify soil staining; however, it was reported that some small spills (less than reportable quantities) may have occurred during transfer operations.

7.1.2 Sampling Rationale

Because of the variability of landfill wastes, it would be exceedingly difficult to characterize them adequately based solely on borehole sampling and analytical testing of the wastes. Discrete waste samples are difficult to obtain, and analytical procedures have not been established to quantify contaminant levels for materials such as paper or metal containers. Therefore, characterization of the source will be accomplished by sampling and testing the pore fluids within the wastes. These fluids consist of leachate below the water level and soil gas above the water level. This approach assumes that the existing landfill leachate and soil gas are representative of the leachate and gas that will be generated in the future and that they will provide an indication of leachable or mobile compounds in the waste. Source characterization based on analysis of leachate and gas sampled directly from the wastes will be supplemented by a comparison of upgradient with downgradient groundwater quality data and sediment sampling in the east pond. All previous and new groundwater data from existing upgradient and downgradient alluvial and bedrock wells will be used in this evaluation. Leachate seeping from the east toe of the landfill wastes and sediments obtained from the upstream end of the existing east pond will also be sampled and analyzed to further characterize the source. It is possible that the existing outlets from the groundwater diversion system contain landfill leachate. Therefore, these outlets will also be sampled and analyzed.

The physical properties and contamination of the soils beneath and downgradient of the source will be characterized by laboratory analysis on soil samples. Soil fill beneath the waste fill and natural alluvial and colluvial soils will be analyzed. In addition, analytical testing will be conducted on samples of the weathered bedrock to evaluate the vertical extent of contamination. Previous work at Rocky Flats indicated that weathered bedrock ranges from 10 to 40 feet in thickness (Rockwell International 1988d). Soil contamination will be evaluated beneath the wastes, at the downstream toe of the landfill, and at the discharge points of the groundwater diversion system. Phase I will evaluate these soils since they are the soils most likely to be contaminated. Further soil characterization would not be warranted if these areas do not show significant contamination. The evaluation of soil contamination will be based on analytical testing of soil samples.

The physical characteristics of the soils will be evaluated based on soil classification and standard geotechnical engineering properties, such as grain size distribution and Atterberg limits. Pump-in borehole permeability tests (packer tests) will also be conducted in the weathered bedrock for use in Phase II RI/FS activities. Soil characterization will not include the existing landfill cover soils, since it is presumed any remedial alternative developed will address these materials along with the wastes. The exception to this is in the Inactive Hazardous Waste Storage Area (SWMU 203), where surficial soil sampling will be conducted to evaluate whether significant near surface contamination is present and/or if special treatment of the soils in this area is warranted.

7.1.3 Sampling Design, Location, and Frequency

7.1.3.1 Present Landfill (SWMU 114)

7.1.3.1.1 Borings. Borings will be drilled at 15 locations throughout the area of the Present Landfill. The boring locations are shown in Plate 7-1. All borings will penetrate the soils and weathered bedrock to the surface of unweathered bedrock. Since the sampling rationale is predicated on the assumption that the overall leachate and soil gas characteristics are indicative of leachable or mobile compounds in the waste, the boring locations are based primarily on site physical characteristic considerations, such as the evaluation of leachate/groundwater flow regime and hydraulic gradients.

All of the borings except Boring Nos. 2 and 6 will be used to obtain soil samples for the purpose of evaluating the vertical extent of soil contamination. Boring Nos. 2 and 6 will be drilled only to obtain samples for geotechnical testing and to construct piezometers for groundwater level measurements. Boring Nos. 1, 3 to 5, and 7 to 12 will be drilled through the landfill waste. Groundwater monitoring wells will be constructed at these 10 locations, with well pairs required at Boring Nos. 10, 11, and 12. Boring Nos. 13 to 15 will not have wells constructed in them and will be abandoned immediately after drilling.

Boring Nos. 1, 4, 8, 10, 11, 12, and 13 are located approximately along the longitudinal axis of the landfill, which should be at the section of deepest fill and which is parallel to the direction of groundwater flow. This will provide information along the entire length of the landfill on groundwater horizontal gradient, the general upgradient to downgradient distribution of contamination, and site physical characteristics such as subsurface profile and geotechnical engineering parameters with depth. Boring Nos. 7 and 9 will provide additional information along the section perpendicular to this axis previously described by Well Nos. 60-87 through 66-87 (Section D-D').

Drilling through the waste is anticipated to require relatively large and specialized drilling equipment. Specific procedures for drilling and sampling will be developed before implementing the Phase I Work Plan. Rigorous compliance with an appropriate health and safety plan will be mandatory. Samples of the waste will be visually classified during drilling, and, although testing of the waste samples is not planned at this time, the samples will be labeled and saved for possible future testing. After drilling to the bottom of the wastes, an 8- to 10-inch-diameter temporary casing will be inserted and sealed at the bottom to isolate the underlying soil and bedrock from the leachate in the wastes. If the soil beneath the waste is coarse, granular material judged to have a permeability on the order of or greater than that of the waste, the casing will be sealed at the top of the weathered bedrock after the soil is sampled as described below.

Soil below the waste in Boring Nos. 1, 3, 4, 5, 7, 8, 9, 10, 11, and 12 and over the entire depth in Boring Nos. 13, 14, and 15 will be sampled using hollow-stem auger continuous coring techniques. Boring No. 12 is located to penetrate the buried west pond. Care will be taken that continuous auger sampling is started at a sufficiently high elevation in Boring No. 12 to sample the pond sediments. In addition, a sample retainer device will be fitted in the tip of the continuous sampler when necessary to assist sample recovery. NX rock core sampling techniques using carbide or diamond bits, which will use potable water from an approved source as the drilling fluid, will be used in at least the bottom 10 feet of each boring. A pump-in borehole permeability test (packer test) will be conducted in the NX-cored section of each boring. From the continuous soil and weathered rock samples, discrete samples will be submitted for laboratory chemical analysis at 2-foot increments in soil and 4-foot increments in weathered rock. Additional samples will be obtained if visual observation or screening indicates significant contamination, such as dense non-aqueous phase liquids, that is not present in the predetermined samples. During drilling, all cuttings and soil samples will be screened with field instruments for radiation and volatile organic compounds.

The exception to the above sampling design will be in Boring Nos. 2 and 6. These two borings will be drilled only for the purpose of classifying soil types and installing standpipe piezometers. Sampling in these borings will consist of standard split-spoon or California drive samples obtained at 5-foot intervals to a depth of approximately 10 feet below the groundwater level. Analytical testing will not be conducted on Boring Nos. 2 and 6 samples.

Table 7-1 presents a summary of estimated boring information. This information is based on interpolations and extrapolations of existing boring and well data. It should be suitable for planning purposes but should not be considered accurate.

7.1.3.1.2 Groundwater Monitoring Wells. Four-inch diameter groundwater monitoring wells will be constructed in Boring Nos. 1, 3, 4, 5, 7, 8, 9, 10, 11, and 12. These wells will be constructed for the purpose of sampling leachate and soil vapor from the wells. Therefore, before construction of the wells, the portions of the borings in soil and rock that are below the bottom of the wastes will be grouted. Removal of the temporary casing previously inserted to the bottom of the waste will be required at the time of well construction.

In wells where the saturated thickness of the waste is 10 feet or less, the entire length of the well will be screened from the bottom to within 5 feet of the ground surface. This will allow sampling of both leachate and soil vapor from the wells. For wells with a saturated thickness of waste of more than 10 feet, well pairs will be constructed. For each pair, one well will be screened in the lower 5 feet and the other well screened from approximately 5 feet below the water level to within 5 feet of the ground surface. The wells in a well pair will be constructed approximately 5 feet apart. The more shallow well will be located upgradient of the deeper well. The purpose for providing well pairs in the larger saturated thicknesses is to reduce contaminant dilution if there are contaminants with concentration gradients with depth.

Four rounds of groundwater and well head-space soil gas samples will be collected during the Phase I RFI/RI process. The first round will immediately follow installation and development of the new wells. The next three rounds will be conducted over approximately the next year; however, the timing will be developed considering previous well hydrographs to sample at times of water level highs and lows. Two of the three rounds following the initial round will be at seasonal highs and lows. The third will be conducted following a significant precipitation event after water levels in the landfill wells show a response to the precipitation. Before sampling, an interface probe will be used to check for the presence of low and high density non-aqueous phase liquids. If they are detected, a discrete sampler will be used to sample them before purging the well for leachate/water samples. Water levels will be measured monthly in each of the wells.

7.1.3.1.3 Piezometers. The cross sections described by Boring Nos. 2, 3, and 4 and by Boring Nos. 4, 5, and 6 intersect the portions of the groundwater diversion and leachate collection system, which may not be keyed into the bedrock. As discussed in subsection 2.1.5.1, the profile sheets in the construction plans (Appendix B) indicate the bottom of the system to be above the bedrock surface at these locations. Groundwater levels along the section described by Well Nos. 10-86, 58-87, B106089, and the new Boring No. 1 will be compared with the groundwater profiles described by the water levels in Well Nos. 2 through 6 to evaluate whether groundwater infiltration is occurring beneath the groundwater diversion and leachate collection system. One-inch diameter standpipe piezometers will be installed in Boring Nos. 2 and 6. These piezometers will be used solely to measure alluvial groundwater levels. They will not be used for obtaining groundwater quality samples. Accordingly, they will be screened from the bottom (approximately 10 feet below the groundwater level) to within 5 feet of the ground surface. Water levels will be measured monthly.

7.1.3.1.4 Sediment Samples. Samples of sediment will be obtained from the east pond at three locations toward the upstream end of the pond. At each of these three locations, a boring will be advanced with hand-operated equipment from a floating platform to obtain a continuous sample of the entire depth of sediments. The thickness of sediments is anticipated to be between 3 and 6 feet. These hand borings may be terminated when hard soil or rock is encountered at the base of the sediments or at a minimum depth of 3 feet. Discrete samples will be submitted for laboratory chemical analysis every 1 foot, with the first sample at the sediment surface.

7.1.3.1.5 Leachate Samples. Samples of leachate seeping from the east toe of the landfill just upgradient of the west end of the east pond will be collected in a reservoir built for this purpose according to the SOP. Seep flows will be measured according to the SOP. The location of the sample station will be identified based on the location of seepage from the toe of the landfill at a dry time when surface runoff is not occurring on the east face of the landfill. If an existing surface water station satisfies this intent, it will be used.

Samples of the effluent from the groundwater diversion system will also be collected from surface water sampling stations SW99 and SW100. Sampling of leachate from the toe of the landfill and surface water stations SW99 and SW100 will be conducted at the same time leachate samples are collected from the wells installed in the landfill.

7.1.3.2 Inactive Hazardous Waste Storage Area (SWMU 203)

The containerized wastes previously stored at the Inactive Hazardous Waste Storage Area generally consisted of 55-gallon drums containing machining waste, cutting and lubricating oils, solvents, organics, and acids stored in cargo containers (subsection 2.1.1.2). Some of the containers were used to store polychlorinated biphenyl (PCB)-contaminated soil and debris, as well as PCB oil from transformers. Residual contaminants that may be present at the Inactive Hazardous Waste Storage Area are volatile organic compounds (VOC), heavy metals, and PCBs. Administrative controls have reportedly precluded the storage of radioactive or mixed wastes at this facility; however, no sampling has been done to support this contention. It is possible that spills occurred during the transfer of materials or from drums that might have leaked while stored on the area.

7.1.3.2.1 Sample Design. Characterization of soil contamination will be conducted following an approach that was developed for the 1988 closure plan (Rockwell International 1988c). The initial characterization effort will consist of (a) visual surveys of the Hazardous Waste Storage Area in order to identify possible spill sites, (b) radiological survey, and (c) organic vapor survey. Soil sampling by stratified and random systematic sampling programs for Target Compound List (TCL) volatile organics, metals, PCBs, and radionuclides will be conducted after the initial surveys. If contamination is found, an additional effort will be undertaken to further define the horizontal and vertical extent of contamination.

7.1.3.2.2. Initial Surveys. The initial visual survey is intended to assist in delineating areas within the facility that will receive stratified sampling. It will consist of looking for signs of spills, such as soil staining.

Radiological and organic vapor field surveys will be conducted near surface. The radiological survey will use a Field Instrument for the Detection of Low Energy Radiation (FIDLER) according to the SOP. The organic vapor survey will be conducted using a portable gas chromatograph (GC). Gas samples from points on a grid will be collected, using a hollow stainless steel tube driven to a depth of 12 inches, and a vacuum sampler. The samples will be analyzed immediately with a portable GC unit. The area to be surveyed corresponds to the area in Figure 7-1 with a reduction in grid size, if necessary, to meet the current SOP requirements.

7.1.3.2.3 Soil Sampling. Soils within the Hazardous Waste Storage Area will be sampled to evaluate the extent of soil contamination. The sampling program will include random systematic sampling and may include some stratified sampling. The random systematic sampling program will include establishing grid points that will be sampled in order to evaluate the probability that a predetermined area of contamination is or is not present at the facility. Stratified sampling will be dependent on the results of the initial surveys. For both sampling methods, it is assumed that the results will indicate if contamination is or is not present.

For Phase I characterization, it is assumed that spills would have resulted in contamination of the near surface soils. Investigation of the potential impact SWMU 203 has had on the underlying landfilled wastes of SWMU 114 is not warranted unless the Phase I investigation reveals that the shallow soils at SWMU 203 are a significant source of contamination. Therefore, preliminary sampling and analyses of soils will be limited to shallow soils up to 12 inches in depth.

7.1.3.2.4 Sampling Procedures. Soil sampling procedures will be the same regardless of whether random systematic or stratified sampling methods are used to identify sampling locations. At each sampling location, a 1-foot-deep boring will be made with hand implements or a bucket auger, depending upon soil conditions. Samples will consist of the composite of materials exposed over the depth of the boring. Samples for volatile organic compounds will be the first sample collected from the boring before mixing to minimize volatization of compounds.

7.1.3.2.5 Random Systematic Sampling. A random systematic sampling grid (Figure 7-1) will be used to determine sampling locations. The grid will be developed using published methods (Zirschky 1984 and Gilbert 1987). The grid points will be sampled regardless of whether they fall within areas delineated by the Phase I surveys. The intent of the random systematic sampling is to identify potential contaminant areas that are not delineated by the Phase I surveys. Since samples may happen to be obtained from grid points within the potentially contaminated areas identified by the Phase I surveys, the grid sampling will also provide data for characterization of these areas. Those areas identified by the Phase I surveys that are not sampled by random systematic sampling procedures will be sampled by stratified sampling, as discussed below.

Parameters governing the size of the random systematic sampling grid are the shape and size of the contaminated area or hot spots of concern and the probability of finding the hot spots. From former practices, drums are generally stored relatively close together, with approximately one-half foot between drums. Using the number of drums added per year to the area and the average spacing between drums, the area occupied by the drums was determined and an equivalent radius, L, of a potential hot spot was calculated. The number of drums and equivalent radius, L, of the potential hot spot for the Hazardous Waste Storage Area will be assumed to be 384 and 20 feet, respectively.

To select the desired probability of finding a contaminated area, the following factors are evaluated:

- The waste characteristics.
- The volume of waste stored.
- The overall risk posed by the wastes.
- The types of sampling programs selected.

Based on available information, the containers were used to store waste oils, organics, solvents, acids, and coolants. It will be assumed that a 70 percent chance of finding a contaminated area is a reasonable goal for preliminary sampling.

Using a 70 percent chance of finding a contaminated area, the procedure to be followed to determine the grid spacing is illustrated in Figure 7-2. The contaminated area that is under investigation, A, is defined by the equivalent area occupied by the maximum number of drums added at the area per year. The ratio of L to G (the grid spacing) is indicated to equal 0.47 (Gilbert 1987) for a circular area with a confidence level of not hitting the target = 0.3. Using this L/G ratio, the information used to determine the grid spacing for a square sampling grid is 42 feet. Based on this grid spacing, a total of 16 random systematic samples will be collected (Figure 7-1).

7.1.3.2.6 Stratified Sampling. The sample distribution for stratified sampling will be based on the results of the initial surveys. Each area of visual soil staining of significant size indicating contamination may be present will be sampled for analyses as will any area that is determined to have surface radiological contamination or volatile organic compounds in the soil gas. One sample will be taken in these areas. Significant size shall be taken as a stain of approximate diameter similar to a 55-gallon drum. Soil stains less than this size will be evaluated in the field based on their size, amount of visual contamination present, similarity, and proximity to other soil staining.

If the random systematic and/or stratified soil sampling described above indicates soil contamination is present, further soil analyses will be conducted to define the extent of contamination and to determine further actions. The additional sampling may be conducted to determine both vertical and horizontal extent of contamination and/or to identify the contamination at a 90 percent confidence level based on a statistically valid analysis. If appropriate, borings will be drilled and sampled as part of continuing Phase I or during Phase II activities. Additional background samples may be required in order to establish background levels in the differing soil horizons encountered in the storage area. The vertical extent of contamination will be determined by extending borings to uncontaminated materials or to the groundwater table, whichever is more shallow.

7.1.3.3 Location Surveying

Locations of all borings and surface sample points will be surveyed to within an accuracy of 1 foot before drilling or sampling. After drilling, all wells and borings will be resurveyed. Horizontal accuracy will be ± 0.5 foot for borings and ± 0.1 foot for wells and piezometers. Vertical accuracy will be ± 0.1 foot for borings, and 0.01 foot for wells and piezometers. Three elevations will be determined for each well/piezometer, ground surface, top of well casing, and top of surface casing.

7.2 SAMPLE ANALYSIS

7.2.1 Soil, Weathered Bedrock, Sediment Samples

7.2.1.1 Chemical Analysis

Soil and sediment samples will be collected as discussed in subsection 7.1. Designated samples will be analyzed for the chemical parameters listed in Table 7-2 following CLP or the methods specified in the Phase I RFI/RI Sample Analysis Plan (SAP). Table 5-1 identifies analytical levels required. Surface soils will be analyzed for the organics, metals, PCBs, and radionuclides as listed in Table 7-2.

7.2.1.2 Soil Gas (Headspace Analysis)

Samples of well headspace gas will be collected from each of the wells. Analysis of samples will be by GC to test for methane, hydrogen sulfide, TCE, toluene, 1,1,1-TCA, benzene, methylene chloride, and chloroform.

7.2.1.3 Physical Analysis

Physical analyses on soil and bedrock samples will consist of laboratory classification, moisture content, and dry density. Laboratory classification tests include grain size distribution and Atterberg limits. Laboratory classifications will be conducted for a minimum of five samples of each general soil or rock material type.

7.2.2 Landfill Leachate and Groundwater Samples

Landfill leachate samples will be collected from all wells screened in the landfill wastes. Groundwater samples will also be obtained from previous upgradient and downgradient wells in the area of the landfill. Logs of previous wells will be checked to ensure they were constructed to satisfy current data quality objectives. Leachate and groundwater samples will be analyzed in the field for Ph, conductivity, and temperature. Laboratory analyses will be performed on unfiltered samples (for leachate) since the objective of the effort is to provide a characterization of contaminants within the landfill. Samples will be analyzed for the parameters listed in Table 7-3. Surface water samples collected from the toe of the landfill and from the groundwater diversion system discharge points will be considered as leachate samples and will be analyzed for the same constituents shown in Table 7-3. This parameter list may be reduced in subsequent sampling events if certain parameter groups are not detected or are not significantly above background levels.

7.2.3 Sample Containers and Preservation, and Sample Control and Documentation

Sample volume requirements, preservation techniques, maximum holding times, and container material requirements are dictated by the media being sampled and by the analyses to be performed. Table 7-4 lists the requirements for samples collected and analyses specified in this

FSP. Field personnel will collect a sufficient volume of each sample in appropriate containers, properly preserved, to allow for the analyses that potentially may be performed on each sample. Additional specific guidance on the appropriate use of materials will be provided in the SOP.

Sample control and documentation are necessary to ensure the defensibility of data and to verify the quality and quantity of work performed in the field. Accountable documents include logbooks, data collection forms, sample labels or tags, chain of custody forms, photographs, and analytical records and reports. Specific guidance defining the necessary sample control, identification, and chain of custody documentation will be discussed in the SOP.

7.2.4 Field QC Procedures

Sample duplicates, field preservation blanks, equipment blanks, and trip blanks will be prepared. The analytical results obtained for these samples will be used to assess the quality of the field sampling effort. The types of field QC samples to be collected and their application are discussed below. The frequency with which each type is to be collected and analyzed is provided in Table 7-5.

Duplicate samples will be collected by the sampling team and will be used as a relative measure of the precision of the sample collection process. These samples will be collected at the same time, using the same procedures, the same equipment, and the same types of containers as Table 7-4 required for the samples. They will also be preserved in the same manner and submitted for the same analyses as required for the samples. Duplicate samples will be media-, parameter-, and event-specific.

Field preservation blanks of distilled water, preserved according to the sampling protocol, will be prepared by the sampling team and will be used to provide an indication of any contamination introduced during the field sample preparation technique. As indicated by Table 7-5, these QC samples are applicable only to samples requiring chemical preservation.

Equipment blanks will be collected from final decontamination rinsate to evaluate the success of the field sampling team's decontamination efforts on nondedicated equipment. Equipment blanks will be obtained by rinsing cleaned equipment with distilled water before sample collection.

Equipment blanks are applicable to all analyses for water and soil samples as indicated in Table 7-5.

Trip blanks consisting of distilled water will be prepared by the laboratory technician and will accompany each shipment of water samples for volatile organic analysis. Trip blanks will be stored with the group of samples with which they are associated. Analysis of the trip blank will indicate any migration of volatile organics or any problems associated with the shipping, handling, or storing of the samples. As indicated in Table 7-5, all blanks will be prepared at a frequency of 1/20 per shipment.

Procedures for monitoring field QC will be given in the QAPP.

8.0
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TABLE 2-1

PRESENT LANDFILL PROPOSED VERSUS ACTUAL CONSTRUCTION DETAILS FOR THE 1989 MONITORING WELLS

Proposed Well No.	Actual Well No.	Proposed Completion Zone	Actual Completion Zone	Proposed Screen Interval (ft.)	Actual Screen Interval (ft.)	Proposed Total Depth (ft.)	Actual Total Depth (ft.)	Reason(s) for Deviations
LF-01	B106089	Qaf	Qaf	13-20	3.66-23.2	20	24.47	Bedrock at 22.7'; screened landfill debris and alluvium.
LF-02	B206189	Kass(w)	Kacl	28-33	25.9-35.36	33	36.61	Screened 5-15' below alluvium/bedrock contract.
LF-03	B206289	Kass(w)	Kacl	28-33	32.37-41.82	33	43.05	Screened sandy interval from 34.5 to 41.0'; no weathered sandstone encountered.
LF-04	B206389	Qaf	Qrf/Qaf	3-15	4.0-13.5	15	14.74	Bedrock at 13.3; screened bottom 10' of alluvium.
LF-05	B206489	Kass(w)	Qrf/Kass(w)	8-18	3.25-10.0	18	11.35	Encountered subcropping sandstone from 7.5-9.5'; screened alluvium and weathered sandstone.
LF-06	B206589	Kass(w)	Kass(w)	15-25	23.5-35.14	25	36.24	Encountered weathered sandstone form 21.5-34.5'; screened bottom 10' of weathered sandstone.
LF-07	Not Drilled	Qrf	N/A	3.5-13.5	N/A	13.5	N/A	Insufficient Qac for completion.
LF-08	B206689	Kacl	Kacl	14.5-24.5	8.7-18.17	24.5	19.41	Screened 5-15' below alluvium/bedrock contact.
LF-09	B206789	Kass(w)	Kacl	13-23	9.8-19.28	23	20.52	Screened 5-15' below alluvium/bedrock contact; no weathered sandstone encountered.
LF-10	B206889	Qc	Kacl	3.5-10	8.0-17.45	10	18.2	Insufficient colluvium for completion; screened 5-15' below colluvium/bedrock contact.
LF-11	B206989	Kacl	Kacl	6-16	11.8-21.3	16	22.5	Screened 5-15' below alluvium/bedrock contact.
LF-12	B207089	Kass(w)	Kass(w)	32.5-53	31.32-53.00	53	54.00	Encountered weathered sandstone and sandy interval 31.5-60.0'; screened upper 20' of sandy interval/sandstone.

TABLE 2-1
(continued)

PRESENT LANDFILL PROPOSED VERSUS ACTUAL CONSTRUCTION DETAILS FOR THE 1989 AND PRESENT MONITORING WELLS

Proposed Well No.	Actual Well No.	Proposed Completion Zone	Actual Completion Zone	Proposed Screen Interval (ft.)	Actual Screen Interval (ft.)	Proposed Total Depth (ft.)	Actual Total Depth (ft.)	Reason(s) for Deviations
LF-13	B207189	Kass(u)	Kass(u)	68-78	70.98-75.43	78	77.76	Screened sandy interval from 70.98-75.43' (based on geophysical logging).
LF-14	B207289	Qrf	Kacl	3.5-13.5	5.2-14.65	13.5	15.89	Moved south due to inaccessibility. Insufficient alluvium for completion; screened 5-15' below alluvium/bedrock contact.
LF-15	Not Drilled	Kacl	N/A	14.5-24.5	NA	24.5	N/A	Insufficient Qc for completion.

(After EG&G 1990a)

Qaf: Artificial fill
Qvf: Valley Fill Alluvium
Qrf: Rocky Flats Alluvium
Qc: Colluvium
Kacl: Weathered Bedrock Claystone
Kass(w): Weathered Bedrock Sandstone
Kass(u): Unweathered Bedrock Sandstone

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Table 2-2
PRESENT LANDFILL RESULTS OF HYDRAULIC CONDUCTIVITY TESTS IN SURFICIAL MATERIALS

Well No.	Formation	Lithology Screened	Drawdown Recovery Test (cm/s)	Slug Tests (cm/s)
45-86	Qrf	Sand and poorly sorted gravel	2.1×10^{-5}	
58-87	Qrf	Sand, poorly sorted gravel, and clayey sand	1.6×10^{-5}	
60-87	Qrf	Sand and gravel grading to clayey sand and clay		1.3×10^{-3}
61-87	Qrf	Sand		9.9×10^{-4}
62-87	Qrf	Sand and gravel, clayey sand and clay		6.2×10^{-4}
63-87	Qrf	Sand and gravel, sandy clay		6.7×10^{-4}
65-87*	Qrf, Kass	Clayey sand, sandstone		4.6×10^{-4}
66-87	Qrf	Sand and sandy clay		1.8×10^{-4}
67-87	Qrf	Clayey sand		6.4×10^{-5}
71-87	Qrf	Clayey sand grading to sandy clay		6.6×10^{-4}
Geometric Mean for Rocky Flats Alluvium			1.8×10^{-5}	4.6×10^{-4}

Qrf = Rocky Flats Alluvium

Kass = Arapahoe Sandstone

	Drawdown Recovery Test (cm/s)	Slug Tests (cm/s)
Geometric Mean for Qrf	1.8×10^{-5}	4.6×10^{-4}

* Completed in two formations. Not used in calculation of geometric mean.

Note: To convert from cm/s to ft/year, multiply by

$$\frac{365.25\ \text{day}}{\text{year}} \times \frac{86400\text{s}}{\text{day}} \times \frac{\text{ft}}{30.48\ \text{cm}}$$

(After EG&G 1990a)

TABLE 2-3

VERTICAL GRADIENTS

Well No.	Elevation of Potentiometric Surface	Water Level Difference (ft)	Saturated Interval Midpoint	Elevation of Saturated Interval	Separator Thickness (ft)	Downview Vertical Gradient
7-86	5920.76		5920.40 - 5917.66	5919.21		
		18.89			56.83	0.33
8-86	5901.87		5864.73 - 5860.02	5862.38		
10-86	5987.93		5991.73 - 5971.24	5979.59		
		20.09			113.32	0.18
9-86	5967.84		5872.66 - 5859.88	5866.27		
40-87	5879.39		5884.19 - 5881.23	5880.31		
		38.44			85.03	0.45
41-87	5840.95		5801.57 - 5788.99	5795.28		

Potentiometric Surface Values Based on April 11, 1988 Measurements

Source: Rockwell International 1988b

Table 2-4

PRESENT LANDFILL RESULTS OF HYDRAULIC TESTS IN THE ARAPAHOE FORMATION

Well No.	Lithology	Drawdown Recovery Test (cm/s)	Slug Test (cm/s)	Packer Test* (cm/s)
8-86	Claystone	-	-	5.7×10^{-7}
	Unweathered Sandstone	7×10^{-8}	-	
9-86	Siltstone	-	-	2.0×10^{-8}
	Unweathered Sandstone	4×10^{-8}	-	9.0×10^{-8}
41-87BR	Claystone	-	-	6.7×10^{-7}
	Unweathered Sandstone	-	2.78×10^{-8}	3.1×10^{-7}
B206589BR	Weathered Sandtone	-	5.8×10^{-6}	
			5.8×10^{-7}	
B207089BR	Weathered Siltstone	-	2.3×10^{-6}	
B207189BR	Unweathered Siltstone	-	1.4×10^{-7}	
			1.5×10^{-7}	

(After EG&G, 1990a)

* Represents geometric mean value from three tests at various intervals

TABLE 2-5
Solid Waste Stream to Landfill
(1986)

BUILDING NO.	WASTE NO.	WASTE NAME	WASTE TYPE	QUANTITY GENERATED	UNITS	GENERATION FREQUENCY
111	06780	developer and fixer containers	empty containers	10	lbs/yr	as needed
111	06630	kimwipes and rags	solid	240		continous
111	06610	toner and dispersant containers	empty containers	3		2 per month
111	06820	empty developer and fixer container	empty containers	100		as needed
111	06680	empty solvent containers	empty containers	3		1 per month
111	06640	empty toner containers	empty containers	10		3 per week
111	06690	kimwipes and rags	solid	240		continous
111	06670	empty ink cans	empty containers	12		3-4 per month
111	06800	kimwipes and filmpacks	solid	100		as needed
111	06650	demineralizer system filters	solid	24		1 per month
111	06760	kimwipes and rags	solid	100		
111	06740	empty chemical containers	empty containers	100		as needed
121	04810	solid waste	solid	100		intermittant
121	04780	gun patches	solid	50		continuous
123	02830	waste resin	aqueous	3		batch
123	03080	batteries,metalwire,used elec.comp.	solid	500		continuous
123	03000	empty vials	solid	100		batch
123	02880	waste resin	solid	50		batch
123	03070	kimwipes	solid	200		continuous
124	01910	settling basin sludge	aqueous	500000	gal/yr	batch
124	00010	microstrainer backwash	aqueous	180000	gal/yr	summer operation
124	00020	clarifier underflow	aqueous	1500000	gal/yr	continuous
124	00030	sand filter backwash	aqueous	1500000	gal/yr	intermittent
124	01660	dried sludge	solid	5000	lbs/yr	once/ 6 months
125	02550	kimwipes	solid	100		continuous
125	02730	oil filters	solid	5		intermittant
130	07350	copy machine toner	empty containers	100		as needed
130	07400	rejected bags	solid	200		as needed
130	07330	polaroid film backings	solid	100		as needed
130	07390	kimwipes	solid	100		as needed
130	07360	packing materials	solid	100		intermittent
130	07380	water conditioning filters	solid	5		twice per month
130	07340	floor sweepings	solid	100		as needed
223	06840	compressor oil filter	solid	1		1 filter/2 years
331	06430	oil filters and used parts	solid	500		daily
331	06440	paint and body-filler cans	solid	200		as needed
333	06230	shavings	solid	100		daily
333	06220	sawdust	solid	100		as needed
333	06110	filters	solid	200		weekly
333	06210	blast waste	solid	1500		as needed
333	06140	empty cans	empty containers	100		as needed
333	06080	empty paint cans	solid	200		as needed
333	06200	scrapings	solid	200		as needed
333	06180	empty cans	empty containers	100		as needed
333	06130	rags	solid	300		as needed
333	06150	disposed equipment	solid	1000		as needed
333	06090	empty paint cans	solid	500		as needed
334	07050	wood/plastic shavings	solid	500		continous
334	07060	floor scrap	solid	200		daily
334	07110	other metal waste	metal	500		
334	06950	enamel residue	solid	100		intermittent
334	07250	miscellaneous solid waste	metal	500		daily
334	07140	scrap metal	metal	500		daily
334	07160	fluorescent light tubes	solid	1000		as needed
334	07120	used filters	solid	2		as needed
334	07130	metal and silica waste	solid	500		intermittent
335	07040	fire extinguisher chemicals	aqueous	200	gal/yr	as needed
373	11640	sump sludge	solid	100	lbs/yr	yearly
439	00070	kimwipes and rags	solid	200		as needed
439	00110	empty cans and containers	empty containers	100		as needed
439	00060	metal chips	metal	500		daily

(After Weston, 1986a, b, c, d, 1987)

Table 2-5
Solid Waste Stream to Landfill
(1986)

BUILDING NO.	WASTE NO.	WASTE NAME	WASTE TYPE	QUANTITY GENERATED	UNITS	GENERATION FREQUENCY
439	00090	kimwipes	solid	200	lbs/yr	as needed
440	00140	aluminum and sst chips	metal	500		
440	00180	kimwipes and rags	solid	500		as needed
440	00160	empty containers	empty containers	100		as needed
440	01390	kimwipes and rags	solid	500		
440	00200	kimwipes and rags	solid	500		as needed
441	00220	toner	empty containers	100		as needed
442	00260	respirator cartridges	solid	100		
442	00250	defective HEPA filters	solid	50		as appropriate
445	15340	trash	solid	500		continuous
445	15280	trash	solid	500		continuous
445	15260	carbon dust	solid	20800		continuous
445	15290	steel shavings	metal	5000		continuous
445	15270	carbon scraps	solid	10000		continuous
445	15300	steel scraps	metal	5000		continuous
449	11070	rags	organic	200		
449	11060	empty paint cans and containers	empty containers	10		
449	11090	miscellaneous trash	solid	660		
454	11890	sump sludge	solid	800		intermittent
457	11860	sump sludge	solid	200		intermittent
460	00910	used kimwipes and floor dry	solid	0		as needed
460	00940	used kimwipes	solid	302		as needed
460	23630	bijur filter screen	solid	2		once/6 mon
460	00600	used kimwipes and rags	solid	200		as needed
460	23770	bijur filter screen	solid			once/6 mon
460	00770	used oil filters	solid	70		as needed
460	23690	air filter	solid	2		once/6 mon
460	00880	metal chips	metal	0		to be determined
460	01000	used kimwipes	solid	55		as needed
460	23710	bijur filter screen	solid	2		once/6 mon
460	00370	used oil filters	solid	20		4 per year
460	01080	kimwipes	solid	150		as needed
460	00840	used kimwipes and floor dry	solid	0		as needed
460	01250	kimwipes and rags	solid	165		as needed
460	23800	bijur filter screen	solid			
460	00460	used kimwipes and rags (vap)	solid	280		as needed
460	01310	kimwipes	solid	50		as needed
460	23680	hydraulic intake filter	solid	2		once/6 mon
460	00640	kimwipes and rags	solid	110		
460	23850	air inlet filter	solid			once/6 mon
460	00810	metal chips	metal	0		to be determined
460	01090	empty paint cans	empty containers	100		
460	23700	bijur filter screen	solid	2		once/6 mon
460	00930	used filters	solid	1800		to be determined
460	01360	kimwipes and floor dry	solid	20		as needed
460	23660	hydraulic system filter	solid	2		once/6 mon
460	01060	discarded containers	empty containers	100		intermittent
460	00890	used kimwipes	solid	0		as needed
460	01050	metal chips	metal	300		to be determined
460	01200	empty chem. and solvent containers	empty containers	100		intermittent
460	01230	kimwipes w/Freon	solid	165		as needed
460	00710	kimwipes, gloves and gauze	solid	0		as needed
460	00710	used kimwipes, gloves and gauze	solid	580		as needed
460	00490	used kimwipes and gloves	solid	110		as needed
460	00950	used kimwipes and floor dry	solid	110		as needed
460	01140	kimwipes and rags	solid	165		as needed
460	00570	nuocure	solid	100		
460	00750	metal chips	metal	0		to be determined
460	23780	bijur filter screen	solid			
460	00380	used kimwipes and gauze	solid	150		as needed
460	01280	kimwipes and floor dry	solid	40		as needed

(After Weston, 1986a, b, c, d, 1987)

Table 2-5
Solid Waste Stream to Landfill
(1986)

BUILDING NO.	WASTE NO.	WASTE NAME	WASTE TYPE	QUANTITY GENERATED	UNITS	GENERATION FREQUENCY
460	00820	used kimwipes	solid	0	lbs/yr	as needed
460	00830	used oil filters	solid	0		as needed
460	01110	empty containers	empty containers	100		intermittent
460	01100	kimwipes and rags	solid	165		as needed
460	00450	used kimwipes and rags (ult)	solid	280		as needed
460	01270	kimwipes	solid	40		as needed
460	23650	apron filter	solid	2		once/6 mon
460	23790	bijur filter screen	solid			once 6/mon
460	01240	empty containers	empty containers	100		as needed
460	09000	used oil filters	solid	0		to be determined
460	23640	turret res. filter	solid	2		once/6 mon
460	23750	inline coolant filter	solid	2		once/6 mon
460	01190	kimwipes	solid	100		as needed
460	01340	kimwipes and rags	solid	60		as needed
460	01170	sludge	solid	1200		to be determined
460	01120	kimwipes and rags	solid	165		as needed
460	00630	film packs	solid	48		
460	01110	empty containers	empty containers	100		intermittent
460	23740	rough inline filter	solid	2		once/6 mon
460	23720	oil filter	solid	2		once/6 mon
460	01070	used kimwipes and floor dry	solid	48		as needed
460	00760	used kimwipes	solid	24000		as needed
460	01320	kimwipes	solid	200		as needed
460	01180	used oil filters	solid	2000		weekly
460	00780	used kimwipes and floor dry	solid	350		as needed
460	00980	metal chips	metal	40		
460	01010	used oil filters	solid	15		as needed
551	06320	metal cuttings	metal	300		
551	06310	spray paint cans	empty containers	100		
551	06300	kimwipes and degreasing residue	solid	300		
560	11810	sump sludge	solid	200		1 to 2 years
563	20580	sump sludge	solid	200		intermittent
662	04040	used filters	solid	20		intermittnat
662	04000	kimwipes	solid	200		continuous
662	04030	broken parts	solid	100		as occurs
664	17500	empty containers	empty containers	100		daily
664	17510	used rags	solid	200		daily
664	17590	solid waste	solid	500		continuous
701	17620	solid waste	solid	200		daily
705	20280	kimwipes	solid	1		as needed
705	20240	polishing pads	solid	2		as needed
705	20300	metal and glass scraps	solid	100		daily
705	20250	kimwipes	solid	3		as needed
705	20620	dumpster	solid			
705	20060	kimwipes	solid	20		as needed
705	20310	office trash	solid	1000		daily
705	20410	sump sludge	solid	20		continuous
708	10650	HEPA filters	solid	200		PMO schedule
709	11700	sump sludge	solid	200		varies
711	20530	sump sludge	solid	200		varies
712	20590	sump sludge	solid	200		varies
713	20600	sump sludge	solid	200		varies
732	15020	filters	solid	300		once per month
750	09100	empty toner/developer containers	empty containers	3		intermittent
750	09020	empty fixer/developer containers	empty containers	100		as required
750	09110	kimwipes	solid	100		intermittent
750	09070	microfilm wrapper	solid	100		continuous
750	09060	empty containers	empty containers	100		intermittent
750	09090	kimwipes	solid	100		intermittent
770	22570	rags	solid	365		occasionally
770	22650	combustibles	solid	4700		daily

(After Weston, 1986a, b, c, d, 1987)

Table 2-5
Solid Waste Stream to Landfill
(1986)

BUILDING NO.	WASTE NO.	WASTE NAME	WASTE TYPE	QUANTITY GENERATED	UNITS	GENERATION FREQUENCY
770	22640	metal chips/scraps	metal	3276	lbs/yr	biweekly
771	22250	empty containers & surgical gloves	solid	5000		every 2 weeks
771	22470	plastic scraps	solid	2900		daily
771	22450	metal chips	metal	3275		weekly
771	22460	combustibles	solid	5000		daily
776	12020	wood & plastic chips/dust	solid	10400		weekly (200 lbs./w
776	12010	empty containers	empty containers	100		occasionally
776	12030	soiled kimwipes	solid	2080		weekly (40 lbs/wk)
776	12040	empty containers	empty containers	2080		weekly (40 lbs/wk)
778	15040	trash in canisters	solid	800		continuous
778	15210	sanitary trash	solid	500		continuous
778	15050	metal/wood shavings	solid	2000		continuous
778	15060	sanitary trash	solid	500		continuous
778	15090	sanitary trash	solid	500		continuous
778	15210	metal/wood shavings	solid	2000		continuous
778	15140	trash	solid	1000		continuous
778	15310	sanitary trash	solid	500		continuous
779	19050	sanitary trash	solid	1300		continuous
779	15480	trash	solid	1000		continuous
779	15400	kimwipes	solid	480		periodically
779	19060	metal shavings/fines	metal	300		continuous
779	15730	water chiller filters	solid	10		monthly
779	15460	plastics grindings	organic	500	gal/yr	continuous
779	19200	machine fines	metal	300	lbs/yr	continuous
779	15410	mixed trash	solid	500		continuous
779	19190	sanitary trash	solid	500		continuous
779	15450	grindings metal	metal	1000		continuous
783	11780	sump sludge	solid	200		intermittent
850	04940	toner and dispersant bottles	empty containers	5		intermittant
865	04240	stainless steel grinding paper	solid	6		per year
865	04280	mold compound	solid	50		
865	04290	photography lab solid wastes	solid	240		
865	04330	metal scraps	metal	260		
881	04670	aerosol, paint and thinner cans	empty containers	200		
881	04620	dirty kimwipes	solid	200		as needed
881	04710	uncontaminated solid waste	solid	5000		
881	04610	other metal chips	metal	600		
881	05070	rags and kimwipes	solid	100		
885	05110	rags	solid	100		
886	03190	copy machine waste	solid	40		
910	06360	diatomaceous earth	solid	54750		weekly/monthly
910	07560	wastewater sludge	solid	0		intermittant
966	06840	empty containers	empty containers	100		intermittent
980	06550	kimwipes	solid	1500		daily
980	06980	sawdust soaked with oil seepage	solid	900		daily
980	06590	metal scrap	metal	5000		daily
980	06530	metal scrap	metal	2000		daily
980	06520	fiberglass resins and catalysts	solid	1000		intermittent
980	06500	metal scraps	metal	5000		daily
980	06570	oily rags	solid	480		daily
980	06510	rags with mineral spirits	solid	1480		daily
980	06490	empty containers	empty containers	100		intermittent
980	06580	oily rags	solid	480		daily
991	07510	toner & dispersant containers	empty containers	100		monthly
991	07500	empty paint containers	empty containers	100		
T750	06010	empty toner/dispersant containers	empty containers	100		monthly
T750	06040	kimwipes	solid	100		as needed
T750	06020	soiled kimwipes	solid	100		as needed

(After Weston, 1986a, b, c, d, 1987)

Table 2-6
Hazardous Waste Stream to Landfill
(1986)

BUILDING NO.	WASTE NO.	WASTE NAME	WASTE TYPE	QUANTITY GENERATED	UNITS	GENERATION FREQUENCY
111	06700	film packs and positives	solid	50	lbs/yr	
123	03100	broken badges	solid	200		as occurs
123	03120	waste vials	solid	100		batch
123	02930	waste resin	solid	5		batch
123	03160	waste resin	solid	100		as required
125	02560	filters	solid	5		Change once/year
125	02640	silicone oil filters	solid	5		
125	02580	kimwipes	solid	100		continuous
334	07070	mineral and asbestos dust	solid	200		as appropriate
367	06930	empty cans, bags and containers	empty containers	100		as needed
377	09960	oil filters	solid	5		pmo schedule
440	01500	kimwipes and rags from paint booth	solid	500		
440	00120	composite kimwipe drum	solid	600		
440	01460	foam trimmings	solid	200		
440	01410	empty paint cans	empty containers	100		
440	00390	metal chip dumpster	solid	2000		
440	00170	R-compound	organic	2640		
440	01470	kimwipes and rags	solid	500		
440	01480	kimwipes and rags	solid	500		
440	01440	kimwipes and rags	solid	500		
440	01420	paint filters	solid	300		
443	00320	contaminated rags	solid	200		as needed
444	14120	sst, iron metal chips	metal	1200		continuous
444	11920	sump sludge	solid	200		varies
453	11130	paper towels	solid	2		intermittent
460	23520	metal chips	metal	0		
460	23560	metal chips	metal	0		
460	01640	air filters	solid	0		
460	23540	metal chips	metal	0		
460	23610	metal chips	metal	0		
460	02350	metal chips	metal	0		
460	02460	metal chips	metal	0		
460	23620	metal chips	metal	0		
460	02300	metal chips	metal	0		
460	01750	metal chip composite	metal	100000		
460	23510	metal chips	metal	0		
460	02290	metal chips	metal	0		
460	02480	metal chips	metal	0		
460	02440	metal chips	metal	0		
460	01650	water filters	solid	0		
460	01830	water filters (x-ray)	solid	50		
460	02280	metal chips	metal	0		
460	01600	compressor filters	solid	40		
460	23580	metal chips	metal	0		
460	02270	metal chips	metal	0		
460	02370	metal chips	metal	0		
460	23550	metal chips	metal	0		
460	01370	film packs	solid	30		
460	02390	metal chips	metal	0		

(After Weston, 1986a, b, c, d, 1987)

Table 2-6
Hazardous Waste Stream to Landfill
(1986)

BUILDING NO.	WASTE NO.	WASTE NAME	WASTE TYPE	QUANTITY GENERATED	UNITS	GENERATION FREQUENCY
460	02410	metal chips	metal	0		
460	02500	metal chips	metal	0		
460	23570	metal chips	metal	0		
460	02340	metal chips	metal	0		
460	00590	mercury light bulbs	solid	5		
460	02320	metal chips	metal	0		
460	02400	metal chips	metal	0		
460	23590	metal chips	metal	0		
460	01780	empty containers	empty containers	100		
460	02380	metal chips	metal	0		
460	02330	metal chips	metal	0		
460	01580	kimwipes and rags	solid	165		
460	02360	metal chips	metal	0		
460	02450	metal chips	metal	0		
460	23600	metal chips	metal	0		
460	23530	metal chips	metal	0		
460	02310	metal chips	metal	0		
460	23470	metal chips	metal	0		
460	02430	metal chips	metal	0		
460	02490	metal chips	metal	0		
460	02420	metal chips	metal	0		
528	15360	kimwipes	solid	10		periodically
549	07300	empty containers	empty containers	100		as needed
562	09840	paper towels with oil	solid	20		varies
668	09570	rags with methyl alcohol	solid	50		intermittant
705	20180	kimwipes	solid	15		as needed
708	10690	rags w/freon and trichloroethane	solid	200		
727	09520	paper towels with oil/freon TF	solid	100		intermittant
771	22010	deionizer exchange resin column	solid	5		yearly
771	22230	bottles, cartons, gloves, kimwipes	solid	15000		continuous
771	22210	liquid chemical containers	solid	4000		continuous
775	22030	trash paper	solid	200		none
776	12120	soiled kimwipes	solid	365		daily
776	12130	empty containers	empty containers	365		daily
776	12100	empty containers	empty containers	365		daily
776	12000	soiled kimwipes	solid	1200		once per day
776	12180	soiled kimwipes	solid	4000		daily
776	12090	soiled kimwipes	solid	365		daily
779	19730	metal chips	metal	10000		2/week
780	09590	rags with trichloroethane	solid	50		infrequent
780	09580	empty paint cans	solid	50		infrequent
881	04660	metal and plastic chips	solid	10000		
881	04760	dirty kimwipes	solid	100		
881	03240	waste resin	solid	4		continuous
886	03180	kimwipes	solid	10		
886	03200	chemicals in cabinet	organic	50		infrequent
910	06340	filter backwash	aqueous	100000		weekly
991	07490	reject rings	solid	1880		weekly

(After Weston 1986a, b, c, d, 1987)

TABLE 2-7
STRONTIUM IN LANDFILL PONDS

MONTH	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973
JAN.	n.a. 2	0.5	<3	3.5 E 7.5 W	3.6 E <3 W	n.a.	n.a.	n.a.	n.a.			n.a.
FEB.	n.a.	<3	<3	<3 E <3 W	3.0 E 3.0 W	n.a. n.a.	n.a.	<3	n.a.	NO DATA AVAILABLE	NO DATA AVAILABLE	n.a.
MAR.	2.3	<3	n.a.	3.2 E 3.2 W	4.6 E <3 W	n.a.	7.2	<3	<3			n.a.
APR.	n.a.	2.4	n.a.	n.a.	<3 E <3 W	n.a.	5.7	<3	<3			n.a.
MAY	n.a.	n.a.	<3	<3	3.5 E <3 W	n.a.	n.a.	<3	3.5			n.a.
JUNE		n.a.	<3	4.2	4.3 E <3 W	n.a	<3	<3	3.3			n.a.
JULY		n.a.	<3	<3	4.3 E <3 W	n.a.	3.3	<3	4			n.a.
AUG.		n.a.	<3	<3	3.5 E 2.1 W	3.2 E	<3	<3	4.5			n.a.
SEP.		n.a.	<3	<3	4.1 E 5.0 W	<3 E	n.a.	n.a.	3			n.a.
OCT.		7.9	<3	<3 3.4 W	4.4 E <3 W	4.3 E <3 W	<3	n.a.	3			16
NOV.		n.a.	<3	<3	3.6 E <3 W	5.8 E <3 W	3.6	n.a.	<10			16
DEC.		n.a.	0.6	<3	3.7 E <3 W	45 E <3 W	n.a	n.a.	NS	3		n.a.

NOTES:
(1) Results prior to April 1983 were for ^{89}Sr+ ^{90}Sr in most cases, except for 1973 and units are pCi/l.
(2) n.a. means not analyzed.
(3) EPA Drinking Water Standard: ^{89}Sr=80pCi/l, ^{90}Sr=8pCi/l.
(4) Local Background for ^{90}Sr=2pCi/l.

(From Rockwell International 1987c)

TABLE 2-8
TRITIUM IN WESTERN LANDFILL POND

MONTH	1980	1979	1978	1977	1976	1975	1974	1973
JAN.	738	1316	1136	1365	1740	1143	n.a.	
FEB.	709	780	1368	922	1733	1429	n.a.	
MAR.	520	844	775	1303	1323	1837	7922	
APR.	886	886	944	1113	1431	924	n.a.	
MAY	639	805	956	818	1121	1445	n.a.	
JUNE	530	816	720	740	1172	984	5875	
JULY	546	694	953	856	1378	1520	4797	
AUG.	508	976	1022	983	1305	1258	3724	
SEP.	576	564	768	863	1143	1777	5056	34,000 39,000 57,000
OCT.	495	938	818	806	869	1762	3304	n.a.
NOV.	490	575	1033	812	1005	1553	1800	n.a.
DEC.	530	436	863	880	1067	1542	n.a.	n.a.

NOTES:

(1) Units are pCi/l.

Source: Rockwell International 1987c

Table 2-9

BACKGROUND GROUND-WATER (ROUND 1)
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE

Analyte	Units	Rocky Flats Alluvium (11 Samples)	Colluvium (2 Samples)	Valley Fill Alluvium (8 Samples)	Weathered Claystone (4 Samples)	Weathered Sandstone (2 Samples)	Unweathered Sandstone (7 Samples)
Dissolved Metals							
Aluminum	mg/l	ND	ND	ND	ND	ND	0.327*
Antimony	mg/l	ND	ND	ND	ND	ND	ND
Arsenic	mg/l	ND	ND	ND	ND	ND	0.0186*
Barium	mg/l	ND	ND	ND	ND	ND	ND
Beryllium	mg/l	ND	ND	ND	ND	ND	ND
Cadmium	mg/l	ND	ND	ND	ND	ND	ND
Calcium	mg/l	85	76.8*	138	73.4*	65.7*	64.6
Cesium	mg/l	ND	ND	ND	ND	ND	ND
Chromium	mg/l	ND	ND	ND	ND	0.0122*	ND
Cobalt	mg/l	ND	ND	ND	ND	ND	ND
Copper	mg/l	ND	ND	ND	ND	ND	ND
Iron	mg/l	0.266*	ND	0.94*	ND	ND	ND
Lead	mg/l	ND	ND	ND	ND	ND	ND
Lithium	mg/l	ND	0.172*	0.028	.031*	0.0106*	ND
Magnesium	mg/l	5.79*	15.3*	26.57	45.3*	9.41*	ND
Manganese	mg/l	0.365	0.088*	0.686*	0.126*	0.292*	0.0182*
Mercury	mg/l	ND	ND	0.003*	.008*	ND	ND
Molybdenum	mg/l	0.0136*	ND	ND	0.015*	0.015*	0.112*
Nickel	mg/l	0.0432*	ND	ND	ND	ND	ND
Potassium	mg/l	7.73*	ND	ND	ND	ND	21.89*
Selenium	mg/l	ND	ND	0.0114*	ND	ND	0.041*
Silver	mg/l	ND	ND	ND	ND	ND	ND
Sodium	mg/l	13.4	98.7*	88	36.9*	25.6*	599
Strontium	mg/l	0.159*	ND	ND	ND	ND	0.451*
Thallium	mg/l	ND	ND	ND	0.01*	ND	ND
Tin	mg/l	ND	ND	ND	ND	ND	
Vanadium	mg/l	ND	ND	ND	ND	ND	ND
Zinc	mg/l	0.141*	ND	0.0212*	0.107*	ND	0.564

(After Rockwell International 1989c)

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Table 2-9
(Continued)

BACKGROUND GROUND-WATER (ROUND 1)
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE

Analyte	Units	Rocky Flats Alluvium (11 Samples)	Colluvium (2 Samples)	Valley Fill Alluvium (8 Samples)	Weathered Claystone (4 Samples)	Weathered Sandstone (2 Samples)	Unweathered Sandstone (7 Samples)
Other							
Total Dissolved Solids	mg/l	352	520*	947	320*	170*	1761
Carbonate	mg/l	ND	ND	ND	ND	ND	49
Bicarbonate	mg/l	436	470*	719	400*	140*	412
Chloride	mg/l	15.6	20*	40.29	11*	15*	607
Sulfate	mg/l	45.1	86*	150	44*	16*	950
Nitrate	mg/l	2.98	0.18*	0.69*	0.58*	1.6*	0.610
Cyanide	----	.0038*	ND	ND	0.0036*	ND	ND
pH		8.6 (5.98)	7.4* (7.1)**	8.68 (6.12)	8.2* (7.4)**	7.5* (7.2)**	10.57 (7.43)***
Dissolved Radionuclides							
Gross Alpha	pCi/l	12.543	27*	13.515	12*	7*	13*
Gross Beta	pCi/l	14.570	12*	18.530	7*	2*	15*
Uranium 233, 234	pCi/l	1.647	11*	6.481	5.8*	1.1*	12.936
Uranium 235	pCi/l	0.000	0.3*	0.232	0.2*	0*	0.135
Uranium 238	pCi/l	0.195	7.7*	5.084	3.2	0.6*	3.3507
Strontium 89, 90	pCi/l	0.552	0.1*	0.878	0.1	-0.1*	0.2*
Plutonium 239, 240	pCi/l	0.009	0*	0.012	0.03	0.01*	0.000
Americium 241	pCi/l	0.000	0*	0.012	0	0.01*	0.019
Cesium 137	pCi/l	0.603	0.2*	0.776	0.4	0.3*	0.7*
Tritium	pCi/l	309	100*	505	100	100*	731

* - Maximum Detected Value
** - Minimum Detected Value
*** - It is conjectured that bentonite may have been introduced into the screened section of the well during placement of the bentonite bottom seal. A bentonite/water slurry has a pH between 10 and 11.
ND - Not Detected at Contract Required Detection Limit
() - Tolerance Internal Lower Limit for Two-Sided Parameter

(After Rockwell International 1989 c)

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TABLE 2-10

ANALYTE CONCENTRATIONS IN LANDFILL POND
COMPARED TO SURFACE WATER CRITERIA

Analyte	Surface Water Concentration Range *	Surface Water Quality Criteria **
METALS (mg/l)		
Silver	<0.01	0.05
Aluminum	0.120-0.704	0.95
Arsenic	<0.01	0.05
Barium	<0.1-.58	1.00
Beryllium	<0.005	0.1
Cadmium	<0.005	0.01
Cobalt	<0.05	NS
Chromium	0.011-0.019	0.05
Cesium	<0.2	NS
Copper	<0.02	1.0
Iron	<0.03-2.3	0.3
Mercury	<0.0002-0.00063	0.002
Mangenese	0.06-0.42	0.05
Molybdenum	<0.1	NS
Nickel	<0.04	0.05
Lead	<0.005	0.005
Antimony	<0.05	NS
Selenium	<0.005	0.01
Strontium	0.4-1.05	NS
Thallium	<0.01	0.015
Vanadium	<0.024	NS
Zinc	<0.02-.89	5.0
MAJOR IONS (mg/l)		
Calcium	40-100	NS
Magnesium	21-75	NS
Sodium	75-226	NS
Potassium	9-68	NS
Chloride	91-124	250
Sulfate	8-52	250
Bicarbonate	190-402	NS

TABLE 2-10
(continued)

Analyte	Surface Water Concentration Range *	Surface Water Quality Criteria **
MAJOR IONS (mg/l) (cont.)		
Nitrate	<0.2	10
TDS	533-1082	500
RADIONUCLIDES (pCI/l)		
Gross Alpha	0(7)-23(11)	15
Gross Beta	11(5)-27(22)	50
Plutonium	0.00(.97-0.02(.05)	40
Uranium		
233 + 234	0.0(2.0-1.1(.2)	40
Uranium 238	0.00(.55)-1.0(.2)	40
Americium	0.00(.51)-0.04(.04)	4
Tritium	110(220)-440	20,000

* Based on August 1986 and September 1987 dta

** From SDWA Maximum Concentration Limit

Source: Rockwell International 1988d

NS - No standard

TABLE 2-11

POTENTIAL RECEPTORS

Exposure Pathway	Route to Receptor	Receptor			
		Human		Biota	
		Area Residents	Site Visitors	Terrestrial	Aquatic
Groundwater	Ingestion	X	X		
	Inhalation	X	X		
	Dermal Contact	X	X		
Wind	Ingestion	X	X	X	
	Inhalation	X	X	X	
	Dermal Contact	X	X	X	
Surface Water and Sediments	Ingestion	X	X	X	X
	Inhalation				X
	Dermal Contact	X	X	X	X

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TABLE 3-1

GENERAL RESPONSE ACTIONS, TYPICAL ASSOCIATED REMEDIAL TECHNOLOGIES, AND EVALUATION

General Response Action	Description	Applicability of General Response Typical Technologies	Action to Potential Pathways
No action	No remedial action taken at site.	Some monitoring and analyses may be performed.	National Contingency Plan requires consideration of no action as an alternative. Would not address potential pathways, although existing access restriction would continue to control onsite contact.
Access and use restrictions	Permanent prevention of entry into contaminated area of site. Control of land use.	Site security; fencing; deed use restrictions; warning signs.	Could control onsite exposure and reduce potential for offsite exposure. Site security fence and some signs are in place. Additional short-term or long-term access restriction would likely be part of most remedial actions.
Containment	In-place actions taken to prevent migration of contaminants.	Capping; groundwater containment barriers; soil stabilization; enhanced vegetation.	If applied to source, could be used to control all pathways. If applied to transport media, could be used to mitigate past releases (except air).
Pumping	Transfer of accumulated subsurface or surface contaminated water, usually to treatment and disposal.	Groundwater pumping; leachate collection; liquid removal from surface impoundments.	Applicable to leachate removal prior to in situ treatment or waste removal. Applicable to removal of contaminated groundwater and bulk liquids (for example, from buried drums).
Removal	Excavation and transport of primarily nonaqueous contaminated material from area of concern to treatment or disposal area.	Excavation and transfer of drums; soils; sediments; wastes; contaminated structures.	If applied to source, could be used to control all pathways. If applied to transport media, will control corresponding pathway. Must be used with treatment or disposal response actions to be effective.

TABLE 3-1
(continued)

General Response Action	Description	Typical Technologies	Applicability of General Response Action to Potential Pathways
Treatment	Application of technology to change the physical or chemical characteristics of the contaminated material. Applied to material that has been removed.	Incineration; solidification; land treatment; biological, chemical and physical treatment.	Applied to removed source material, could be used to control all pathways. Applied to removed transport media, could control air, surface water, groundwater, and sediment pathways.
In situ treatment	Application of technologies in situ to change the in-place physical or chemical characteristics of contaminated material.	In situ vitrification, densification, flushing, bioremediation.	Applied to source, could be used to control all pathways. Applied to transport media, could be used to control corresponding pathways.
Storage	Temporary stockpiling of removed material in a storage area or facility prior to treatment or disposal.	Temporary storage structures.	May be useful as a means to implement removal actions, but definition would not be considered a final action for pathways.
Disposal	Final placement of removed contaminated material or treatment residue in a permanent storage facility.	Permitted landfill; repositories.	With source removal, could be used to control all pathways. With removal of contaminated transport media, could be used to control corresponding pathway (except air).
Monitoring	Short- and/or long-term monitoring is implemented to assess site conditions and contamination levels.	Sediment, soil, surface water, and groundwater sampling and analysis.	RCRA requires post-closure monitoring to assess performance of closure and corrective action implementation.

TABLE 5-1

SUMMARY OF DATA QUALITY OBJECTIVES (DQO)
PRESENT LANDFILL AND INACTIVE HAZARDOUS WASTE STORAGE SITE
PHASE I RFI/RI WORK PLAN

Data Needs	Sample and Analysis Methods	Analytical Levels[a]	Data Uses
Characterize the Site Physical Features			
Soil types, engineering properties	Geotechnical testing on samples from boreholes.	II	Evaluation of remedial alternatives
Alluvial groundwater flow regime for the landfill area	Measure water levels in new and existing wells installed in the landfill.	I	Evaluation of remedial alternatives
Characterize Contaminant Sources			
Characterize the nature of waste materials in landfill	Collect leachate samples from groundwater monitoring wells installed directly into the landfill and from seepage at east toe of landfill. Analyze TCL organic, inorganic, and metals and radionuclide constituents.	IV (V for radiological analyses)	Baseline Risk Assessment and alternatives evaluation.
	Collect headspace gas samples from each borehole/well. Analyze methane, hydrogen sulfide, and other gases.	II	Site Characterization and alternatives evaluation.

TABLE 5-1
(continued)

Data Needs	Sample and Analysis Methods	Analytical Levels[a]	Data Uses
<u>Characterize Contaminant Sources</u> (continued)			
	Collect samples of sediment from the east pond. Measure TCL organic, inorganic, and metals and radionuclide constituents.	IV (V for radiological analyses)	Baseline Risk Assessment and Alternatives Evaluation.
Identify groundwater contaminant sources	Evaluate previous and new groundwater quality data from upgradient and downgradient water quality monitoring wells.	III	Contaminant migration evaluation and Baseline Risk Assessment.
<u>Characterize the Nature and Extent of Soil Contamination</u>			
Determine if contaminants are present in surficial soils at the Inactive Hazardous Waste Storage Area	Collect soil scrapes (<12" depth) from the storage area. Analyze samples for organics, PCB's and radionuclides.	III	Site Characterization.
	Conduct surface radiological survey using a FIDLER.	II	Site Characterization.

TABLE 5-1
(continued)

Data Needs	Sample and Analysis Methods	Analytical Levels[a]	Data Uses
<u>Characterize the Nature and Extent of Soil Contamination</u> (continued)			
Determine if contamination has occurred in soils beneath and downgradient of the landfill wastes	Collect soil and bedrock samples from borings. Analyze TCL organic, inorganic, and metals as well as radionuclide constituents.	IV (V for radiological analyses)	Site characterization, Baseline Risk Assessment and Alternatives Evaluation.

[a] For explanation, see Table 5-2

TABLE 5-2
LEVEL OF ANALYSIS

REQUIRED ANALYTICAL LEVEL	TASK
Level I (Field Screens)	o Water level measurement o pH measurement o Eh measurement o Screening for organics (OVA/HNu) o Screening for radionuclides (beta-gamma) o Temperature o Specific conductance o Screening for burried objects (magnetometer, pipe locator)
Level II (Field Analyses)	o Screening for organics (GC) o Screening for metals (ICP) o Screening for radionuclides (gross beta/gross alpha gamma spec) o Analysis of engineering properties
Level III (Laboratory Analyses using EPA Standard Methods)	o Major ion analysis o Organics analysis o Inorganics analysis
Level IV (Laboratory Analyses using EPA CLP Methods)	o Analysis of TCL compounds
Level V (Nonstandard Analyses)	o Radiological analyses o Chemical analyses requiring modification of standard methods

Source: EPA (1987)

TABLE 6-1

EPA GUIDANCE DOCUMENTS THAT WILL BE USED IN THE RISK ASSESSMENT TASK

Risk Assessment Guidance for Superfund, Human Health Evaluation Manual Part A, Interim Final (EPA 1989a)

Superfund Exposure Assessment Manual (EPA 1988d)

Exposure Factors Handbook (EPA 1989b)

The Endangerment Assessment Handbook (EPA 1985)

CERCLA Compliance with Other Laws Manual (EPA 1988e)

Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (EPA 1988a)

Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference (EPA 1989c)

Risk Assessment Guidance for Superfund -- Environmental Evaluation Manual (EPA 1989d)

Data Quality Objectives for Remedial Response Activities: Development Process (EPA 1987)

TABLE 7-1

PROPOSED BORING SUMMARY

Boring	Well*	Piezometer**	ESTIMATED ELEVATIONS (ft)***				Estimated Saturated Waste Thickness (ft)***	Estimated Total Boring Depth (ft)***/****	Estimated Well/ Piezometer Depth (ft)
			Ground	Water	Bottom of Waste	Top of Bedrock			
1	X		5992	5980	5977	5968	3	34-64	15
2		X	5988	5980	NA	NA	NA	18	18
3	X		5988	5977	5981	5975	NA	23-53	7
4	X		5988	5975	5969	5969	6	29-59	19
5	X		5990	5977	5985(?)	5977	NA	23-53	5
6		X	5990	5980	NA	NA	NA	20	20
7	X		5986	5970	5966	5958	4	38-68	20
8	X		5987	5970	5968	5961	2	36-66	19
9	X		5986	5970	5965	5965	5	31-61	21
10	X		5983	5965	5951	5951	14*****	42-72	32/13
11	X		5983(?)	5960	5940	5935	20*****	58-88	43/28
12	X		5983(?)	5955	5938	5930	17*****	63-93	45/33
13			5922	5921	NA	5918	NA	14-44	NA
14			5886	5885	NA	5880	NA	16-46	NA
15			5910	5905	NA	5900	NA	20-50	NA

* Wells screened in wastes (see text).
** Standpipe piezometers screened from bottom to within 5 feet of ground surface.
*** Approximate values based on review of available data.
**** Based on 10 to 40 feet of bedrock penetration.
*****Two separate wells.

TABLE 7-2

PHASE I RI
SOURCE SAMPLING PARAMETERS
SOIL SAMPLES

METALS

Target Analyte List - Metals
- Aluminum
- Antimony
- Arsenic
- Barium
- Beryllium
- Cadmium
- Calcium
- Chromium
- Cobalt
- Copper
- Iron
- Lead
- Magnesium
- Manganese
- Mercury
- Nickel
- Potassium
- Selenium
- Silver
- Sodium
- Thallium
- Vanadium
- Zinc

Other Metals
- Molybdenum
- Cesium
- Strontium
- Lithium
- Tin

INORGANICS
- pH
- Nitrate
- Percent Solids

ORGANICS

Target Compound List - Volatiles
- Chloromethane
- Bromomethane
- Vinyl Chloride
- Chloroethane
- Methylene Chloride
- Acetone
- Carbon Disulfide
- 1,1-Dichloroethene
- 1,1-Dichloroethane
- total 1,2-Dichloroethene
- Chloroform
- 1,2-Dichloroethane
- 2-Butanone
- 1,1,1-Trichloroethane
- Carbon Tetrachloride
- Vinyl Acetate
- Bromodichloromethane
- 1,1,2,2-Tetrachloroethane
- 1,2-Dichloropropane
- trans-1,2-Dichloropropene
- Trichloroethene

TABLE 7-2
(continued)

ORGANICS (CONT.)

Target Compound List - Volatiles (Continued)

- Dibromochloromethane
- 1,1,2-Trichloroethane
- Benzene
- cis-1,3-Dichloropropene
- Bromoform
- 2-Hexanoe
- 4-Methyl-2-pentanone
- Tetrachloroethene
- Toluene
- Chlorobenzene
- Ethyl Benzene
- Styrene
- Total Xylenes
- 1,1-Dichloroethane

Target Compound List -- Semi-volatiles

- Phenol
- bis(2-Chloroethyl)ether
- 2-Chlorophenol
- 1,3-Dichlorobenzene
- 1,4-Dichlorobenzene
- Benzyl Alcohol
- 1,2-Dichlorobenzene
- 2-Methylphenol
- bis(2-Chloroisopropyl)ether
- 4-Methylphenol
- N-Nitroso-Dipropylamine
- Hexachloroethane
- Nitrobenzene
- Isophorone
- 2-Nitrophenol
- 2,4-Dimethylphenol
- Benzoic Acid
- bis(2-Chloroethoxy)methane
- 2,4-Dichlorophenol
- 1,2,4-Trichlorobenzene
- Naphthalene
- 4-Chloroaniline
- Hexachlorobutadiene
- 4-Chloro-3-methylphenol(para-chloro-meta-cresol)
- 2-Methylnaphthalene
- Hexachlorocyclopentadiene
- 2,4,6-Trichlorophenol
- 2,4,5-Trichlorophenol
- 2-Chloronaphthalene
- 2-Nitroaniline
- Dimethylphthalate
- Acenaphthylene
- 3-Nitroaniline
- Acenaphthene
- 2,4-Dinitrophenol
- 4-Nitrophenol
- Dibenzofuran
- 2,4-Dinitrotoluene
- 2,6-Dinitrotoluene

TABLE 7-2
(continued)

ORGANICS (CONT.)

Target Compound List -- Semi-volatiles (continued)

- Diethylphthalate
- 4-Chlorophenyl Phenyl ether
- Fluorene
- 4-Nitroaniline
- 4,6-Dinitro-2-methylphenol
- N-nitrosodiphenylamine
- 4-Bromophenyl Phenyl ether
- Hexachlorobenzene
- Pentachlorophenol
- Phenanthrene
- Anthracene
- Di-n-butylphthalate
- Fluoranthene
- Pyrene
- Butyl Benzylphthalate
- 3,3'-Dichlorobenzidine
- Benzo(a)anthracene
- bis(2-ethylhexyl)phthalate
- Chrysene
- Di-n-octyl Phthalate
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Benzo(a)pyrene
- Indeno(1,2,3-cd)pyrene
- Dibenz(a,h)anthracene
- Benzo(g,h,i)perylene

Target Compound List -- Pesticides/PCBs

- alpha-BHC
- beta-BHC
- delta-BHC
- gamma-BHC (Lindane)
- Heptachlor
- Aldrin
- Heptachlor Epoxide
- Endosulfan I
- Dieldrin
- 4,4'-DDE
- Endrin
- Endosulfan II
- 4,4'-DDD
- Endosulfan Sulfate
- 4,4'-DDT
- Endrin Ketone
- Methoxychlor
- alpha-Chlordane
- gamma-Chlordane
- Toxaphene
- AROCLOR-1016
- AROCLOR-1221
- AROCLOR-1232
- AROCLOR-1242
- AROCLOR-1248
- AROCLOR-1254
- AROCLOR-1260

TABLE 7-2
(continued)

RADIONUCLIDES	
	Gross Alpha
	Gross Beta
	Uranium 233+234, 235 and 238
	Americium 241
	Plutonium 239+240
	Tritium
	Strontium 90, 89
	Cesium 137

TABLE 7-3

PHASE I RI
LANDFILL LEACHATE AND GROUNDWATER

FIELD PARAMETERS
- pH
- Specific Conductance
- Temperature

INDICATORS
- Total Dissolved Solids

DISSOLVED METALS
- Target Analyte List - Metals
  - Aluminum
  - Antimony
  - Arsenic
  - Barium
  - Beryllium
  - Cadmium
  - Calcium
  - Chromium
  - Cobalt
  - Copper
  - Iron
  - Lead
  - Magnesium
  - Manganese
  - Mercury
  - Nickel
  - Potassium
  - Selenium
  - Silver
  - Sodium
  - Thallium
  - Vanadium
  - Zinc
- Other Metals
  - Molybdenum
  - Strontium
  - Cesium
  - Lithium
  - Tin

ANIONS
- Carbonate
- Bicarbonate
- Chloride
- Sulfate
- Nitrate as N
- Cyanide

ORGANICS
- Target Compound List - Volatiles
  - Chloromethane
  - Bromomethane
  - Vinyl Chloride
  - Chloroethane
  - Methylene Chloride
  - Acetone
  - Carbon Disulfide
  - 1,1-Dichloroethene
  - 1,1-Dichloroethane
  - total 1,2-Dichloroethene
  - Chloroform

TABLE 7-3
(continued)

ORGANICS (CONT.)

Target Compound List - Volatiles (Continued)

1,2-Dichloroethane
2-Butanone
1,1,1-Trichloroethane
Carbon Tetrachloride
Vinyl Acetate
Bromodichloromethane
1,1,2,2-Tetrachloroethane
1,2-Dichloropropane
trans-1,3-Dichloropropene
Trichloroethene
Dibromochloromethane
1,1,2-Trichloroethane
Benzene
cis-1,3-Dichloropropene
Bromoform
2-Hexanone
4-Methyl-2-pentanone
Tetrachloroethene
Toluene
Chlorobenzene
Ethyl Benzene
Styrene
Total Xylenes

Target Compound List -- Semi-volatiles

Phenol
bis(2-Chloroethyl)ether
2-Chlorophenol
1,3-Dichlorobenzene
1,4-Dichlorobenzene
Benzyl Alcohol
1,2-Dichlorobenzene
2-Methylphenol
bis(2-Chloroisopropyl)ether
4-Methylphenol
N-Nitroso-Dipropylamine
Hexachloroethane
Nitrobenzene
Isophorone
2-Nitrophenol
2,4-Dimethylphenol
Benzoic Acid
bis(2-Chloroethoxy)methane
2,4-Dichlorophenol
1,2,4-Trichlorobenzene
Naphthalene
4-Chloroaniline
Hexachlorobutadiene
4-Chloro-3-methylphenol(para-chloro-meta-cresol)
2-Methylnaphthalene
Hexachlorocyclopentadiene
2,4,6-Trichlorophenol
2,4,5-Trichlorophenol
2-Chloronaphthalene
2-Nitroaniline
Dimethylphthalate
Acenaphthylene

TABLE 7-3
(continued)

ORGANICS (CONT.)

Target Compound List -- Semi-volatiles (Continued)

3-Nitroaniline
Acenaphthene
2,4-Dinitrophenol
4-Nitrophenol
Dibenzofuran
2,4-Dinitrotoluene
2,6-Dinitrotoluene
Diethylphthalate
4-Chlorophenyl Phenyl ether
Fluorene
4-Nitroaniline
4,6-Dinitro-2-methylphenol
N-nitrosodiphenylamine
4-Bromophenyl Phenyl ether
Hexachlorobenzene
Pentachlorophenol
Phenanthrene
Anthracene
Di-n-butylphthalate
Fluoranthene
Pyrene
Butyl Benzylphthalate
3,3'-Dichlorobenzidine
Benzo(a)anthracene
bis(2-ethylhexyl)phthalate
Chrysene
Di-n-octyl Phthalate
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(a)pyrene
Indeno(1,2,3-cd)pyrene
Dibenz(a,h)anthracene
Benzo(g,h,i)perylene

Target Compound List -- Pesticides/PCBs

alpha-BHC
beta-BHC
delta-BHC
gamma-BHC (Lindane)
Heptachlor
Aldrin
Heptachlor Epoxide
Endosulfan I
Dieldrin
4,4'-DDE
Endrin
Endosulfan II
4,4'-DDD
Endosulfan Sulfate
4,4'-DDT
Endrin Ketone
Methoxychlor
alpha-Chlordane
gamma-Chlordane
Toxaphene
AROCLOR-1016

TABLE 7-3
(continued)

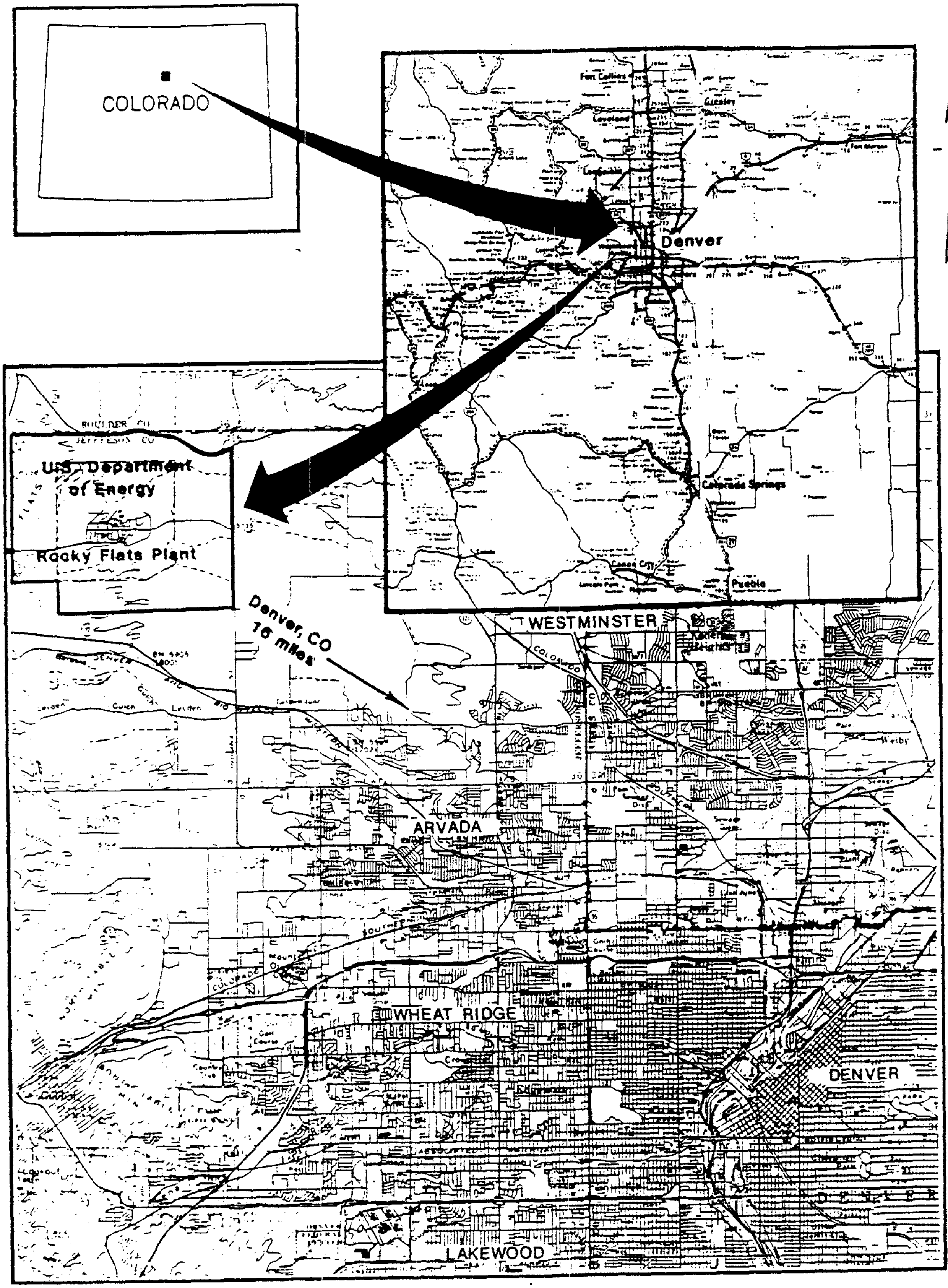
ORGANICS (CONT.)

Target Compound List -- Pesticides/PCBs (continued)

- AROCLOR-1221
- AROCLOR-1232
- AROCLOR-1242
- AROCLOR-1248
- AROCLOR-1254
- AROCLOR-1260

RADIONUCLIDES

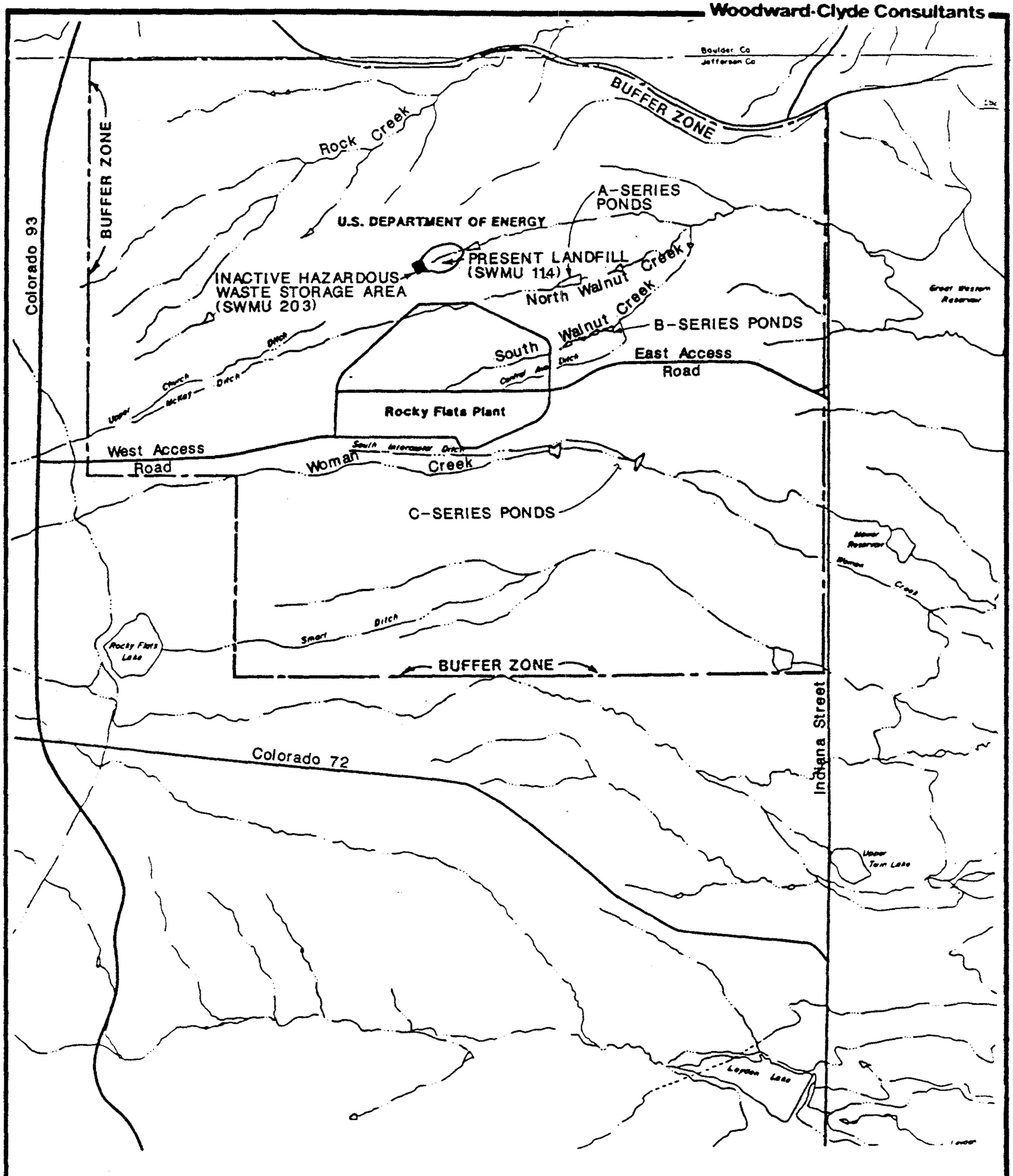
- Gross Alpha
- Gross Beta
- Uranium 233+234, 235, and 238
- Americium 241
- Plutonium 239+240
- Tritium
- Cesium 137
- Strontium 90
- Radium 226, 228



Not To Scale

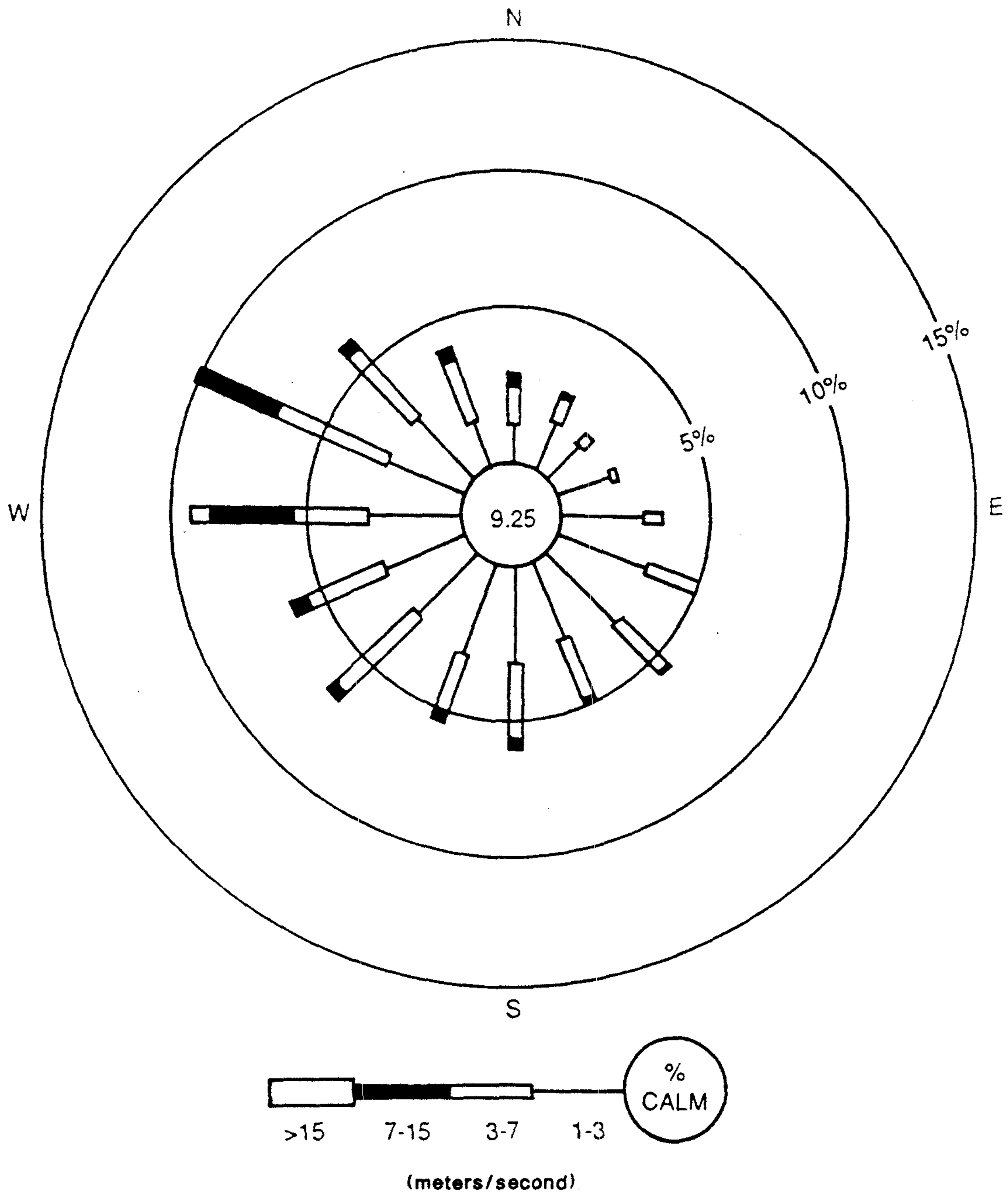
Job No. : 4004-410	LOCATION MAP
Prepared by : A.C./T.K	
Date : 5/4/90	Figure 1-1

SOURCE: ROCKWELL INTERNATIONAL 1989e



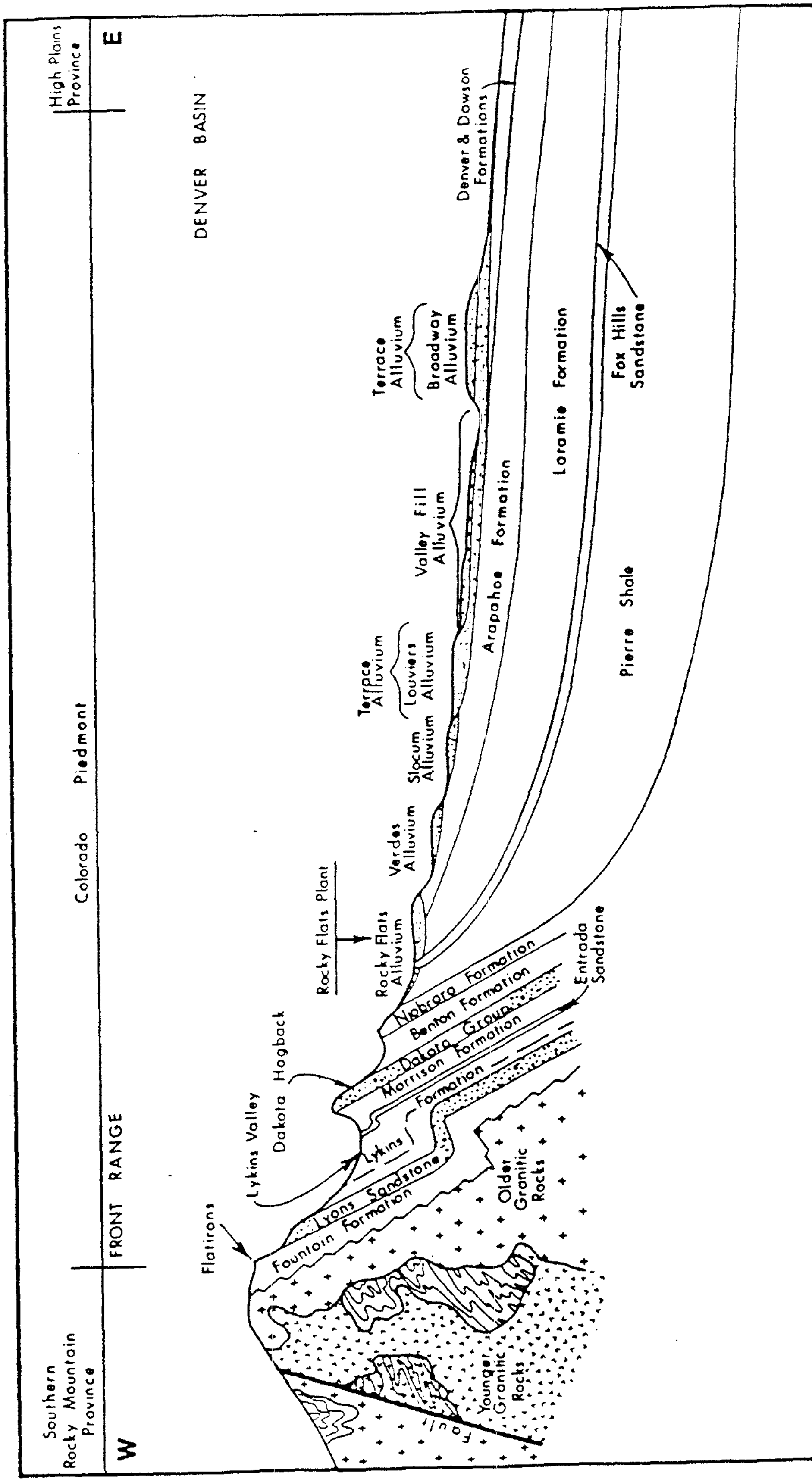
Job No. : 4004-410	ROCKY FLATS PLANT BOUNDARIES AND BUFFER ZONE
Prepared by : A.F.C./T.K.	
Date : 5/4/90	Figure 1-2

SOURCE: ROCKWELL INTERNATIONAL 1989e



SOURCE: ROCKWELL INTERNATIONAL 1989b

Job No. : 4004-410	1988 ANNUAL WIND ROSE FOR THE ROCKY FLATS PLANT
Prepared by : A.F.C./T.K.	
Date : 5/4/90	Figure 1-3

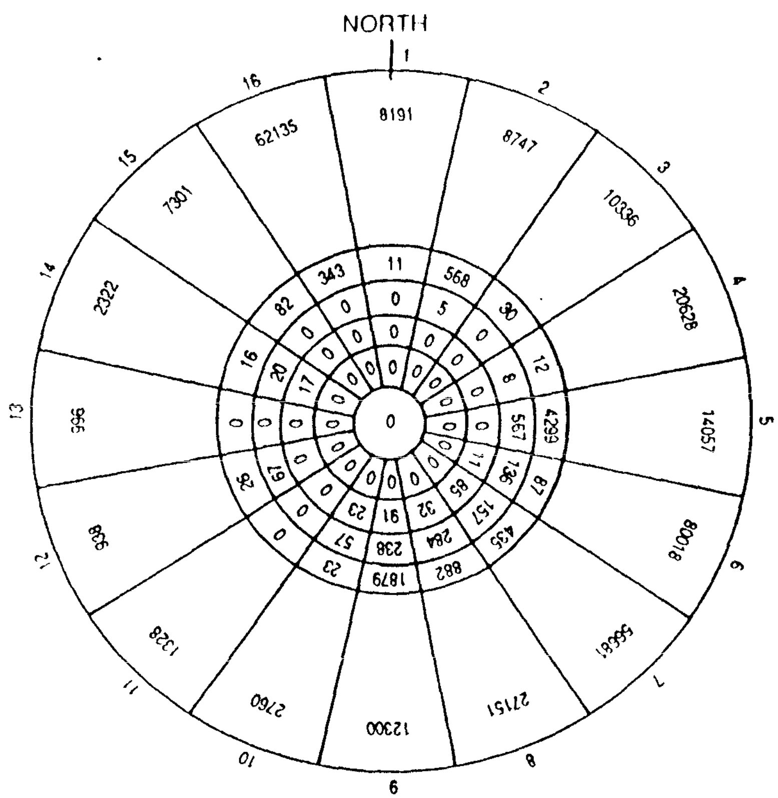


Not To Scale

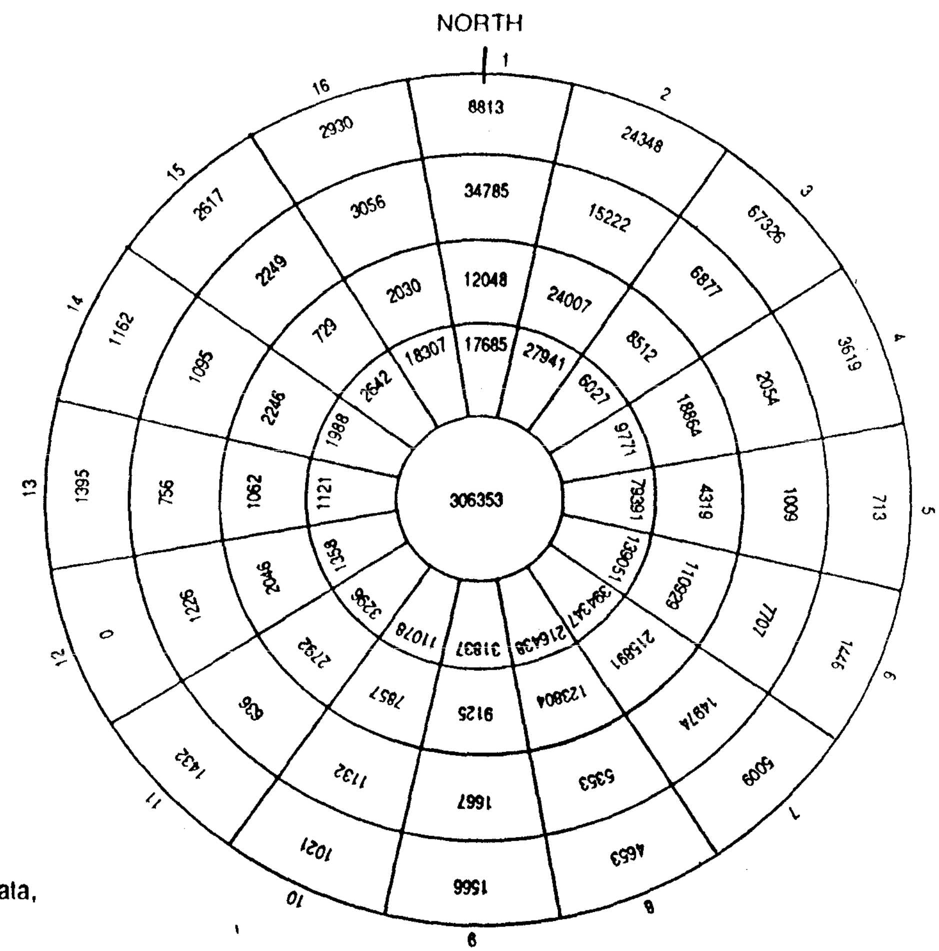
(after: Boulder County Planning Commission, 1983 and Scott, 1960)

SOURCE: ROCKWELL INTERNATIONAL 1988d

Job No. : 4004-410	GENERALIZED EAST-WEST CROSS SECTION FRONT RANGE TO DENVER BASIN
Prepared by : A.C./T.K	
Date : 5/4/90	Figure 1-4



0 TO 16 km (0 to 10 miles) FROM ROCKY FLATS[b]



16 TO 80 km (10 to 50 miles) FROM ROCKY FLATS[c]

a. These population estimates were calculated from 1980 census tract data, assuming uniform population distribution throughout each section.

b. Concentric circles represent 1.6- to 3.2-, 3.2- to 4.8-, 4.8- to 8.0-, 8.0- to 16.0-km (1- to 2-, 2- to 3-, 3- to 4-, 4- to 5-, and 5- to 10-mi) bands.

c. Concentric circles represent 16- to 32-, 32- to 48-, 48- to 64-, 64- to 80- km (0- to 20-, 20- to 30-, 30- to 40-, 40- to 50- mi) bands.

SOURCE: ROCKWELL INTERNATIONAL 1989b

Job No. : 4004-410	1988 DEMOGRAPHIC ESTIMATES
Prepared by : A.C./T.K	
Date : 5/4/90	Figure 1-5

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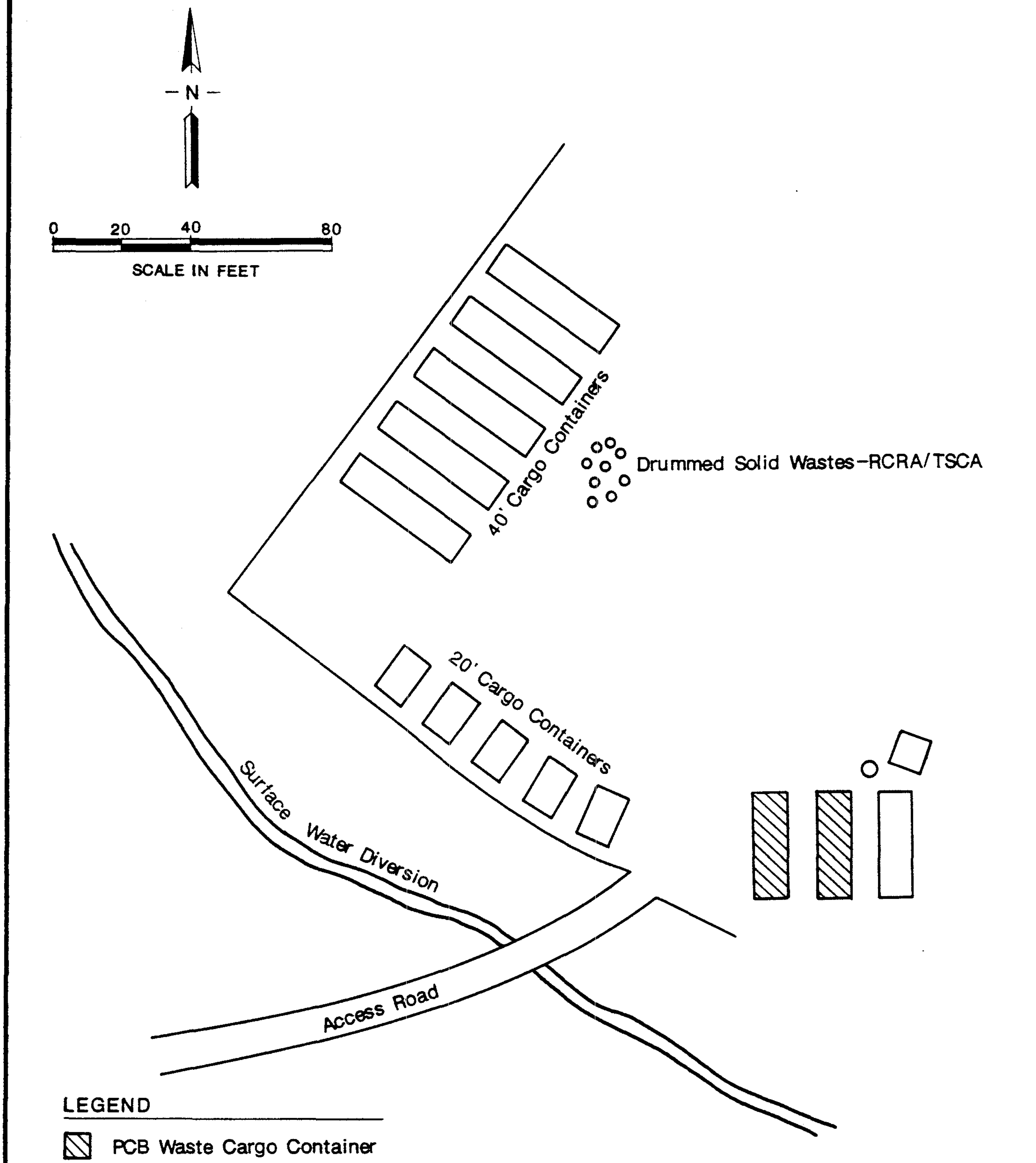
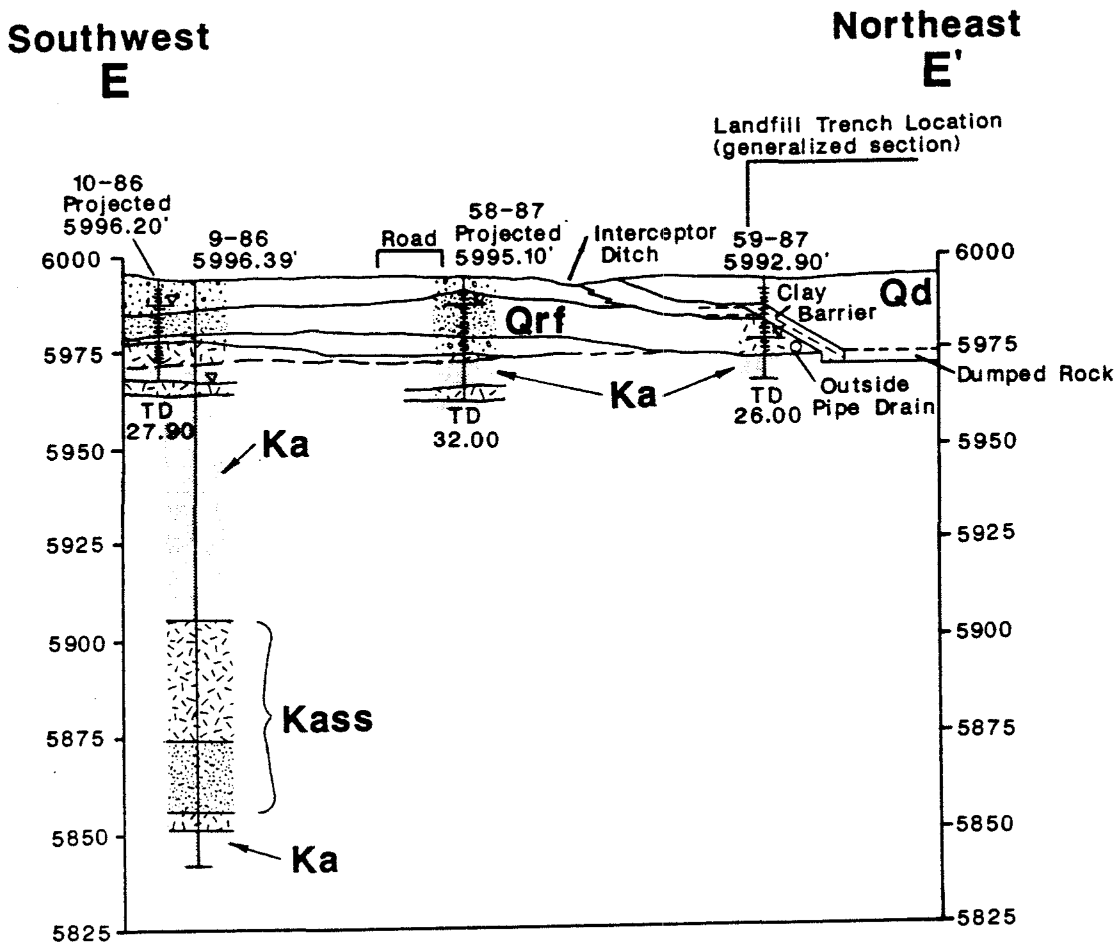


SOURCE: ROCKWELL INTERNATIONAL 1988c

Job No. : 4004-410	INACTIVE HAZARDOUS WASTE STORAGE AREA SWMU Ref. No. 203
Prepared by : A.C./T.K.	
Date : 5/4/90	Figure 2-1



41-87
5931-56'

WELL IDENTIFICATION
GROUND SURFACE ELEVATION (SURVEYED)

WATER LEVEL (MEASURED 4/11/88)

GEOLOGIC CONTACT (dashed where inferred)

SCREENED INTERVAL

TD 110.00' TOTAL DEPTH DRILLED

QUATERNARY

- Qc Colluvium
- Qd Disturbed Ground
- Qrf Rocky Flats Alluvium
- Qvf Valley Fill Alluvium

CRETACEOUS

- Ka Arapahoe Formation (Claystone)
- Kass Arapahoe Formation (Sandstone
- Clay
- Clayey Sand or Sandy Clay
- Sand and/or Sandstone
- Sand and/or Gravel
- Silt and/or Siltstone
- Claystone

SOURCE: ROCKWELL INTERNATIONAL 1988d

Job No. : 4004-410	CROSS SECTION E-E'
Prepared by : A.C.	
Date : 5/4/90	Figure 2-5

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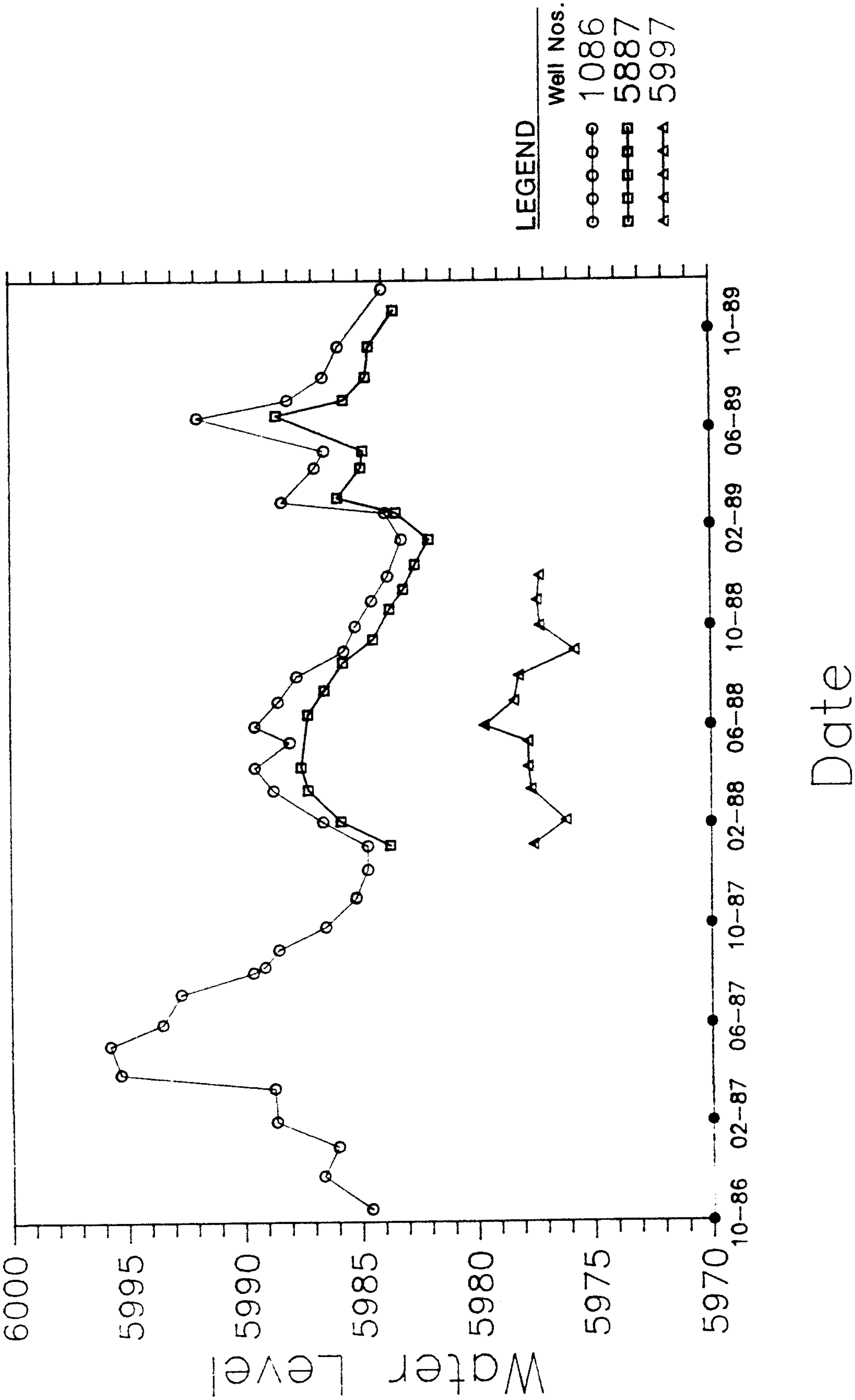
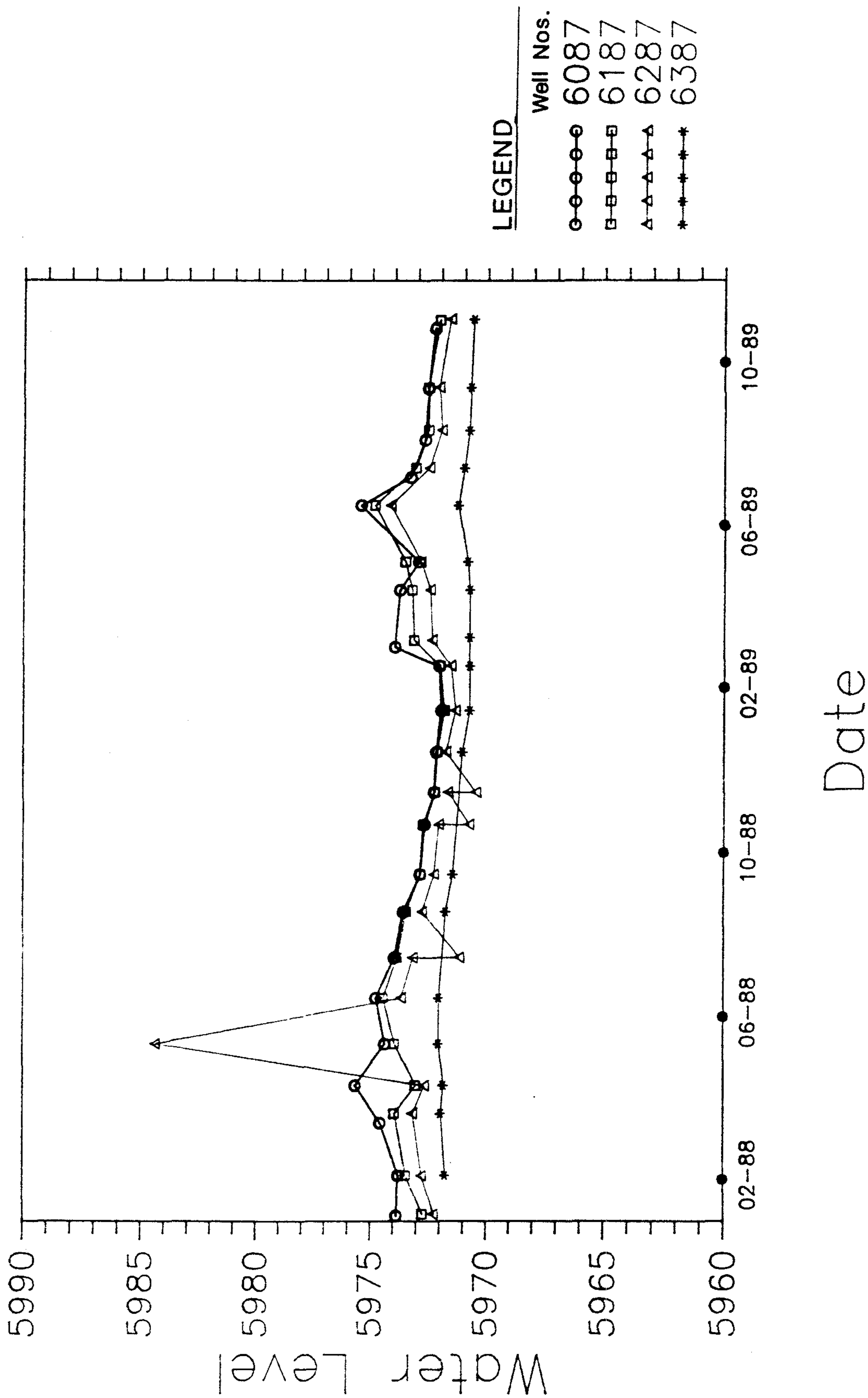
Woodward-Clyde Consultants



Job No. : 4004-410	GROUNDWATER LEVEL HYDROGRAPH SECTION E-E'
Prepared by : A.C.	
Date : 5/4/90	Figure 2-6

134376

Woodward-Clyde Consultants



Job No. : 4004–410	GROUNDWATER LEVEL HYDROGRAPH NORTH END SECTION D–D'
Prepared by : A.C.	
Date : 5/4/90	Figure 2–7

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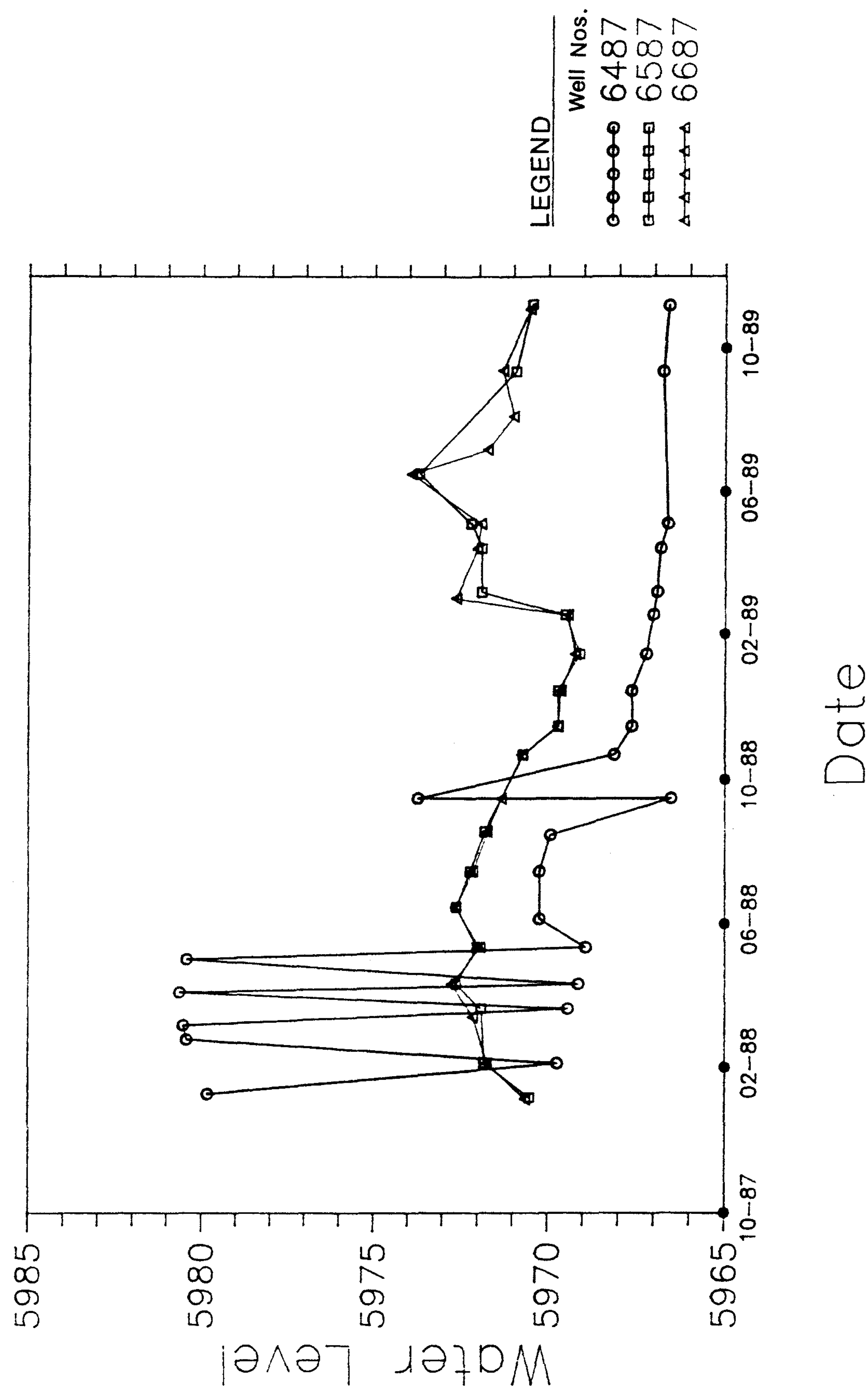
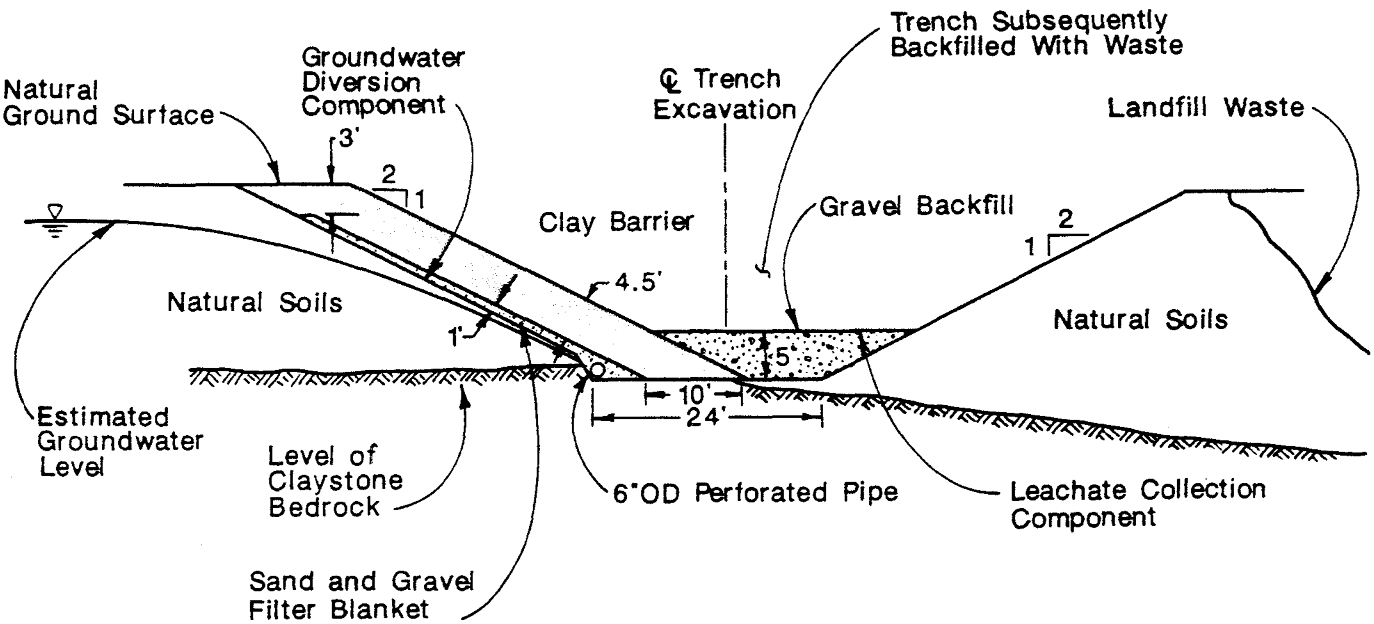
Woodward-Clyde Consultants



Job No. : 4004-410	GROUNDWATER LEVEL HYDROGRAPH SOUTH END SECTION D-D'
Prepared by : A.C.	
Date : 5/4/90	Figure 2-8

134376

Woodward-Clyde Consultants



APPROXIMATE SCALE 1"=20'

SOURCE: ROCKWELL INTERNATIONAL 1988d

Job No. : 4004-410	DESIGN SECTION OF GROUNDWATER DIVERSION AND LEACHATE COLLECTION SYSTEM
Prepared by : A.C.	
Date : 5/4/90	Figure 2-10

PHASE I RFI/RI SCHEDULE - SWMUs 114 AND 203

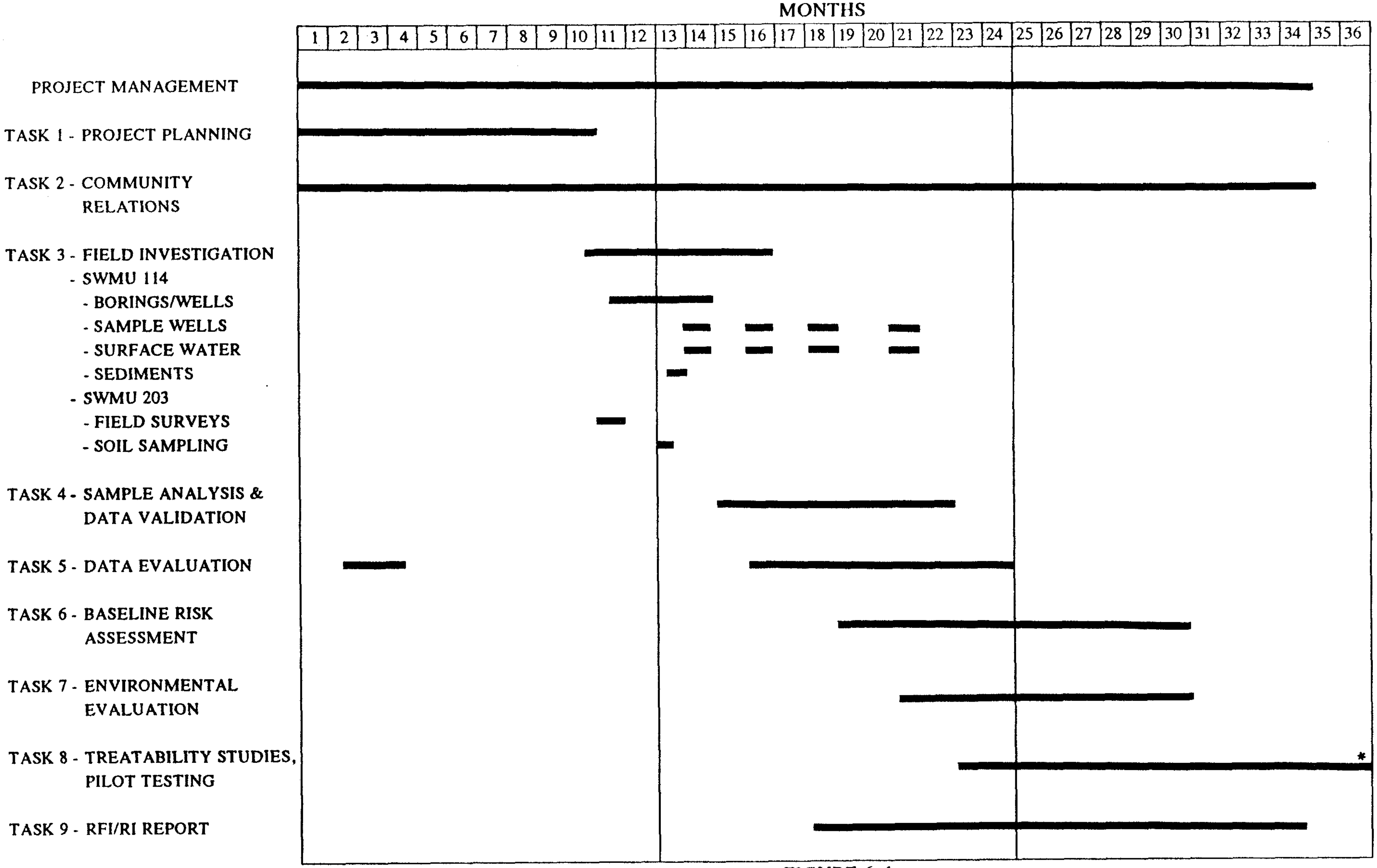
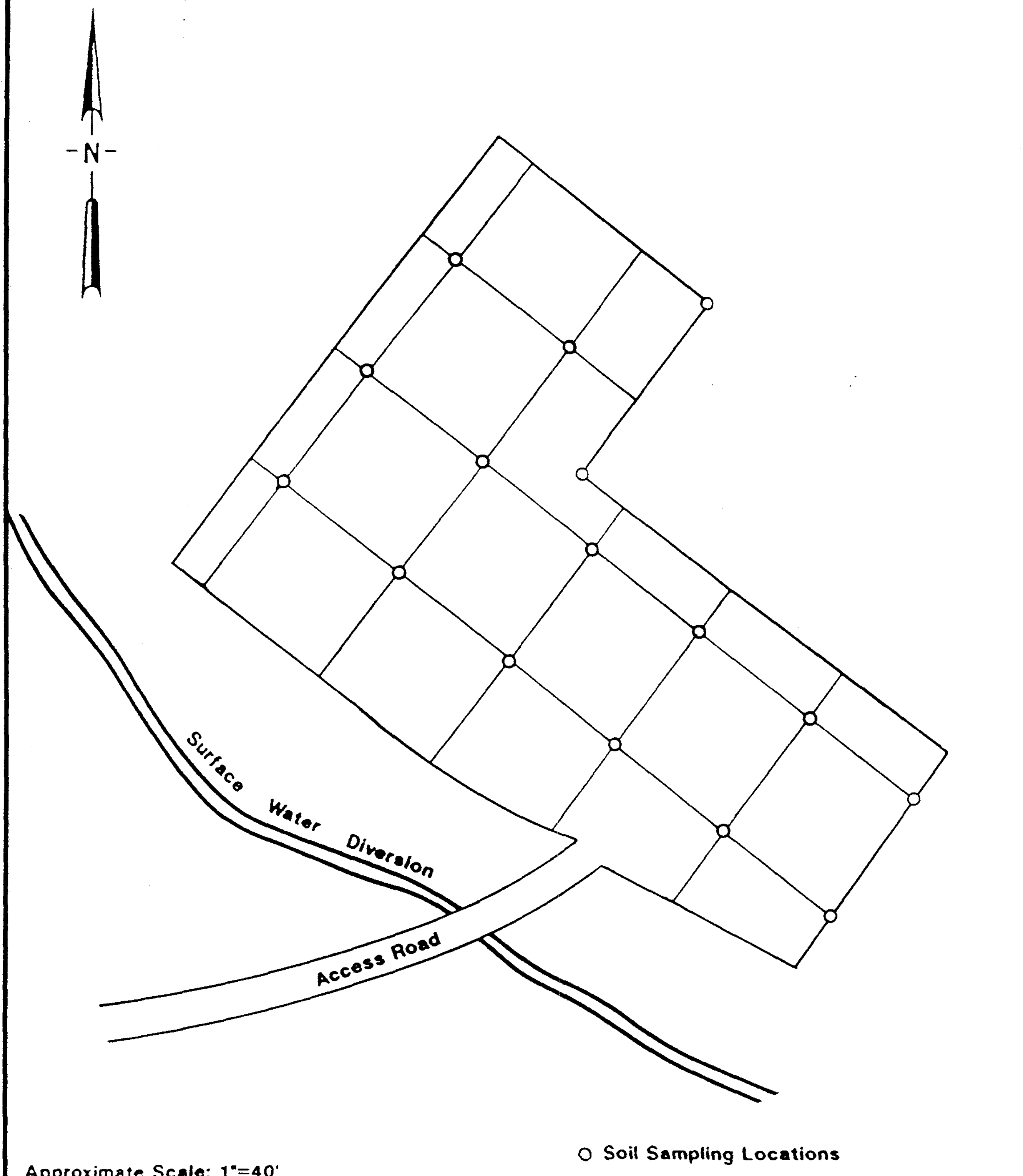


FIGURE 6-1

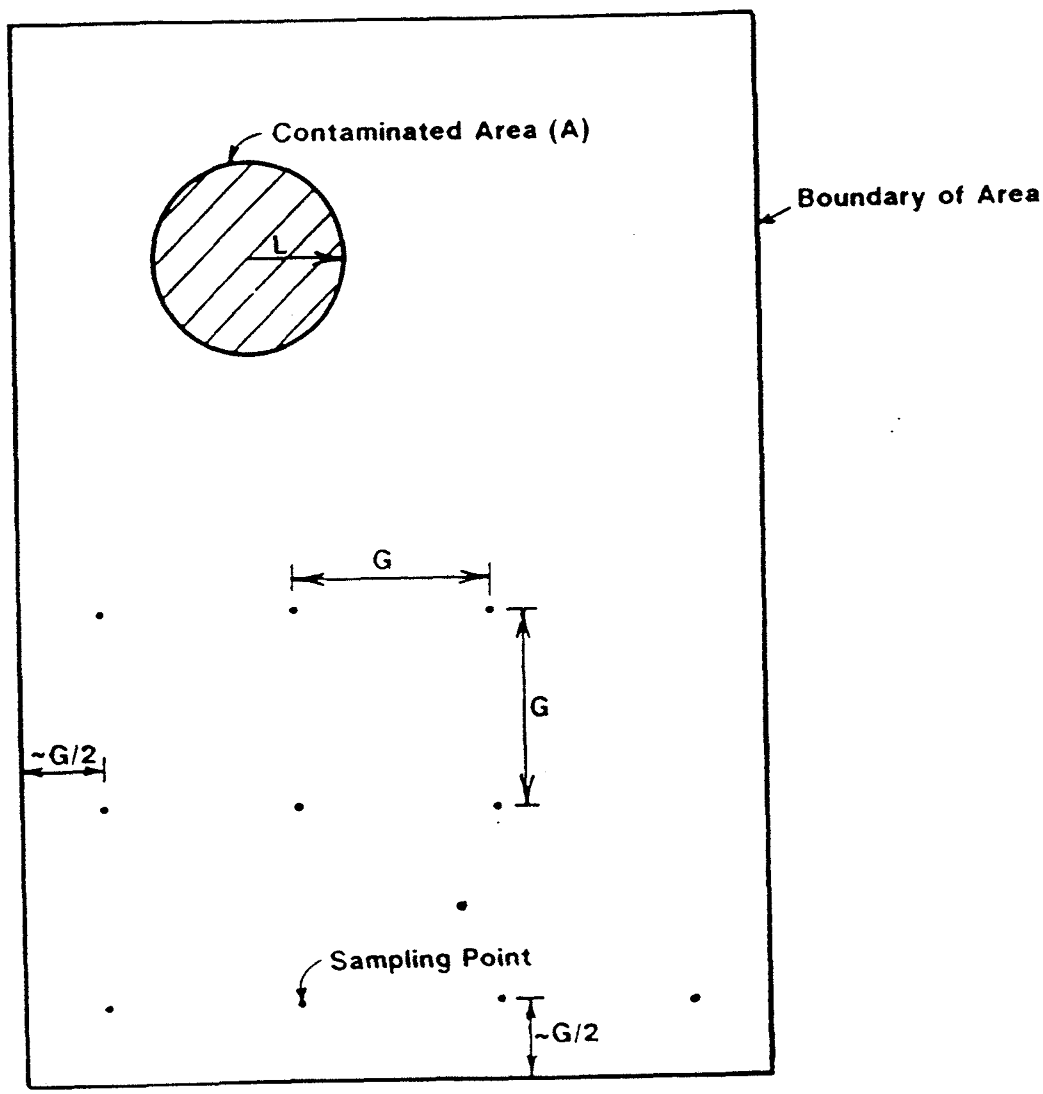
* SITE-WIDE TREATABILITY STUDIES CONTINUE BEYOND PHASE I RFI/RI REPORT COMPLETION.

(FLATS\BARCHART.WK1)cm



SOURCE: ROCKWELL INTERNATIONAL 1988c

Job No. : 4004-410	RANDOM SAMPLING LOCATIONS HAZARDOUS WASTE STORAGE AREA
Prepared by: A.C./T.K.	
Date: 5/4/90	Figure 7-1



L=Equivalent Radius (ft) Based on Maximum Number of Drums Added to Storage

A=Equivalent Area (sq. ft.) = πL^2

B=0.3 (B= Probability of Not Hitting the Target = 1−0.7)

L/G=0.47

SOURCE: ROCKWELL INTERNATIONAL 1988c

Job No. : 4004-410	RANDOM SAMPLING GRID
Prepared by : A.C./T.K.	
Date : 5/4/90	Figure 7-2

NOTICE

This document (or documents) is oversized for 16mm microfilming, but is available in its entirety on the 35mm fiche card referenced below:

Document # 000040

Titled: Proposed Field Sampling Locations Phase 1 RFI/RI Plate 7-1

Fiche location: A-04Ø7-M1

NOTICE

This document (or documents) is oversized for 16mm microfilming, but is available in its entirety on the 35mm fiche card referenced below:

Document # 000040

Titled: Present Landfill Site Plan, and Locations of Wells and Sections Plate 2-1

Fiche location: A-OU07-M1

APPENDIX A
PRESENT LANDFILL HYDROGEOLOGIC CHARACTERIZATION REPORT

(Copies of Plates have been reduced to 11" x 17" size and are not to scale.)

PRESENT LANDFILL

HYDROGEOLOGIC CHARACTERIZATION REPORT

ROCKY FLATS PLANT

GOLDEN, COLORADO

JULY 1, 1988

Prepared for:

Rockwell International
Aerospace Operations
Rocky Flats Plant
Golden, Colorado 80401

Prepared by:

Roy F. Weston, Inc.
215 Union Boulevard
Suite 600
Lakewood, Colorado 80228

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SECTION 1

CONCLUSIONS AND RECOMMENDATIONS

Hydrogeologic investigation results of the Present Landfill suggest landfill may not be completely isolated from ground water exterior to the landfill by the ground-water intercept system. However, ground-water quality impacts from the landfill are within natural variations observed in ground-water in the vicinity of the landfill.

Hydraulic assessments for specific areas on the west, north, and south sides of the ground-water intercept system indicate ground water does not migrate into the landfill at all locations along intercept system. However, water balance calculations indicate ground water inflow probably occurs around the landfill. The intersection of the ground-water intercept system and the slurry walls may be the location of this inflow.

Based upon an examination of alluvial water quality data from wells within and surrounding the landfill it appears the landfill may be contributing calcium, bicarbonate, and to a lesser extent sodium, sulfate, iron, manganese, and strontium to the ground water. However, ground water to the north of the north slurry wall (presumably not influenced by the landfill) has similar concentrations of these analytes. This implies that even if the landfill contributes these constituents to the ground water, the resulting concentrations are within natural variations for the area. With respect to the public health significance of the water quality directly downgradient of the landfill (well 42-87), only iron (0.40 mg/l) and manganese (0.57 mg/l) exceed the ground-water quality criteria (0.3 and 0.05 mg/l, respectively).

However, manganese also exceeds the criterion (maximum concentration of 0.63 mg/l) in upgradient ground water, and it is not elevated with respect to upgradient conditions.

It is concluded that the landfill does not alter alluvial ground-water quality relative to the natural variations in the vicinity of the landfill and relative to public health-based water quality criteria. High salt concentrations further down the drainage (wells 6-86 and 5-86) appear to result from another yet unidentified and presumably natural source.

Bedrock ground-water quality is conjectured to be influenced largely by mineral dissolution within the sandstones and claystone. High salt concentrations observed in bedrock wells are not seen in alluvial ground water within the landfill.

An impermeable cap will be placed on the Present Landfill area during closure to eliminate precipitation infiltration. This cap will aid in removing water currently present by reducing recharge to the landfill. However, the effectiveness of this plan is dependent upon the ability of the in-place ground-water collection system to effectively divert ground water away from the landfill. Therefore, the following future actions are recommended to evaluate the performance of the collection system. These activities will be completed within one year.

1) Well 59-87 should be abandoned because the borehole penetrates the clay surface seal of the ground-water/leachate collection system. This well should be replaced by another alluvial monitoring well located approximately 80 feet northeast of well 59-87 along cross-section line E-E'. This new well will allow continued monitoring of water levels within the landfill waste.

2) An addition alluvial monitoring well will be installed approximately 100 feet north of well 72-87. By installing this well, a well pair will be established straddling the south slurry trench . Single hole pump tests will then be performed on well 68-87 and the proposed new well, with 67-87 and 72-87 serving as the observation wells during these tests. The

effectiveness of the slurry trenches will then be assessed based on the response of these observation wells to the pumped wells.

3) A bedrock monitor well will be installed adjacent to well 64-87 and completed in the sandstone unit subcropping in this area. An additional bedrock well will also be installed approximately 350 feet east of well 64-87 and completed in the same sandstone unit. This sandstone should be encountered approximately 43 feet below ground surface based on a seven degree easterly dip. A comparison can then be made between bedrock water quality inside and outside of the Present Landfill.

4) Single hole pump tests should be conducted in wells 63-87, 64-87, and the replacement well for 59-87 with wells 62-87, 65-87, and 58-87 serving as the observation wells, respectively. These tests will serve to establish if a hydraulic connection exists between alluvial ground-water inside and outside of the landfill at these locations.

5) The valves present along the ground-water collection system outside pipe drain will be exposed to determine where the water is being diverted.

6) The areas where the north and south slurry trenches are keyed into the outside pipe drain will be uncovered and examined to determine if a blockage of the drain occurred during this constriction.

7) Monthly monitoring of ground-water levels within the landfill will continue to establish seasonal variations in water levels.

Additional bedrock monitoring well be installed and field tests will also be performed to further characterize the bedrock hydrogeology at the Present Landfill. The following recommendations are provided to meet this objective.

1) An additional bedrock monitor well will be installed approximately 170 feet east of well 8-86 to verify the sandstone unit subcrop beneath the landfill pond. The unit should be encountered at approximately one to five feet below ground surface and should extend to a depth of approximately 21 feet below ground surface. The lithology of this sandstone will be compared to the description of the completion sandstone of 41-87BR to verify the correlation.

2) A bedrock well will be installed approximately 75 feet east of well 72-87 (along Cross-section line C-C') to verify the thickness of the subcropping sandstone present in wells 70-87 and 72-87. The subcropping sandstone should be encountered at approximately eight feet below ground surface. The borehole will fully penetrate the sandstone unit to determine the thickness of the bed, and the well will be screened across the entire sandstone thickness.

3) Two additional bedrock monitor wells will be installed near well 41-87BR. One of these wells will be completed in the uppermost sandstone unit encountered in 41-87BR (approximately 33 feet below ground surface). The second well will be completed in the middle sand found in 41-87BR approximately 48 feet below ground surface. These additional wells will help formulate an assessment of the bedrock ground-water quality leaving the present landfill area.

4) Slug tests will be conducted in all newly installed wells as well as in wells 40-87 and 42-87 to determine the hydraulic conductivity of the valley fill alluvium.

Finally, additional sampling programs for both surface water and ground water are recommended for continued monitoring as follows.

1) Continue sampling and measuring flow rates of leachate discharging from the landfill toe to assess water quality and water balance.

2) Monitor spray rates from the landfill pond.

3) Continue monitoring flow rates and water quality from the ground-water interceptor outlets.

4) Conduct a full year of ground-water sampling to confirm analytical results.

5) Conduct quarterly sampling and flow measurements at surface water stations LFP,SW13, SW14, and SW15 (Plate 5-1) to evaluate temporal variations in water quality and flow rates.

SECTION 2

INTRODUCTION

This report presents a geologic and hydrogeologic characterization of the Present Landfill. The landfill at the Rocky Flats Plant was first identified as a RCRA regulated unit in the fall of 1986 when the facility Part B application was in preparation. At that time, it was determined that certain waste streams being disposed at the landfill were RCRA hazardous wastes. Shortly thereafter, it was determined that continued disposal of hazardous wastes at the landfill would cease. Hence, a closure plan for interim status closure of the landfill is required pursuant to Part 265 of the Colorado State Hazardous Waste Regulations (6 CCR) and Title 40, Part 265 of the Code of Federal Regulations (40 CFR). The goal of the closure plan is to meet closure performance standards as follows:

- The owner or operator must close the facility in a manner that: a) minimizes the need for further maintenance; and b) controls, minimizes or eliminates, to the extent necessary, to protect human health and the environment, post-closure escape of hazardous waste constituents, leachate, contaminated rainfall, or waste decomposition products to the ground or surface waters or to the atmosphere (6 CCR and 40 CFR 265.111).

- The owner or operator must provide a detailed description of the steps needed to remove or decontaminate all hazardous waste residues and contaminated containment system components, equipment, structures, and soils during partial and final closure including, but not limited to, procedures for cleaning equipment and removing contaminated soils, methods for sampling and testing surrounding soils, and criteria for determining the extent of decontamination necessary to satisfy the closure performance standard [6 CCR at 40 CFR 265.112(b)(4)].

- The owner or operator must provide a detailed description of other activities necessary during partial and final closure period to ensure that all partial and final closure satisfy the closure performance standards, including, but not limited to, ground-water monitoring, leachate collection, and run-on and run-off control [6 CCR and 40 CFR 265.112(b)(5)].

- o During the partial and final closure periods, all contaminated equipment, structures and soil must be properly disposed of, or decontaminated unless specified otherwise in 265.228 or 265.310 (6 CCR and 40 CFR 265.114).

- o If the owner or operator does not remove all the impoundment materials (standing liquids, waste and waste residues, liners, underlying and surrounding contaminated soil), he must close the impoundment and provide post-closure care as for a landfill under Subpart G (6 CCR and 40 CFR 265.110-265.120 and 265.310; 6 CCR and 40 CFR 265.228 (a,b,c)).

- o At final closure of the landfill or upon closure of any cell, the owner or operator must cover the landfill or cell with a final cover designed and constructed to provide long-term minimization of migration of liquids through the closed landfill; function with minimum maintenance; promote drainage and minimize erosion or abrasion of the cover; accommodate settling and subsidence so that the covers' integrity is maintained; and have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present (6 CCR and 40 CFR 265.310).

A closure plan was submitted on November 28, 1986, for the landfill as part of the RCRA Post Closure Care Permit Application for the Rocky Flats Plant (Rockwell International, 1986a). It was prepared in accordance with 6 CCR and 40 CFR 265. Interpretations and conclusions incorporated in this report supersede those in the 1986 Post Closure Care Permit Application.

2.1 REPORT OVERVIEW

This report provides results of the 1986 and 1987 site characterization investigation performed at the Present Landfill at Rocky Flats Plant. Historical aerial photographs and previous investigations were also sources of information for this report.

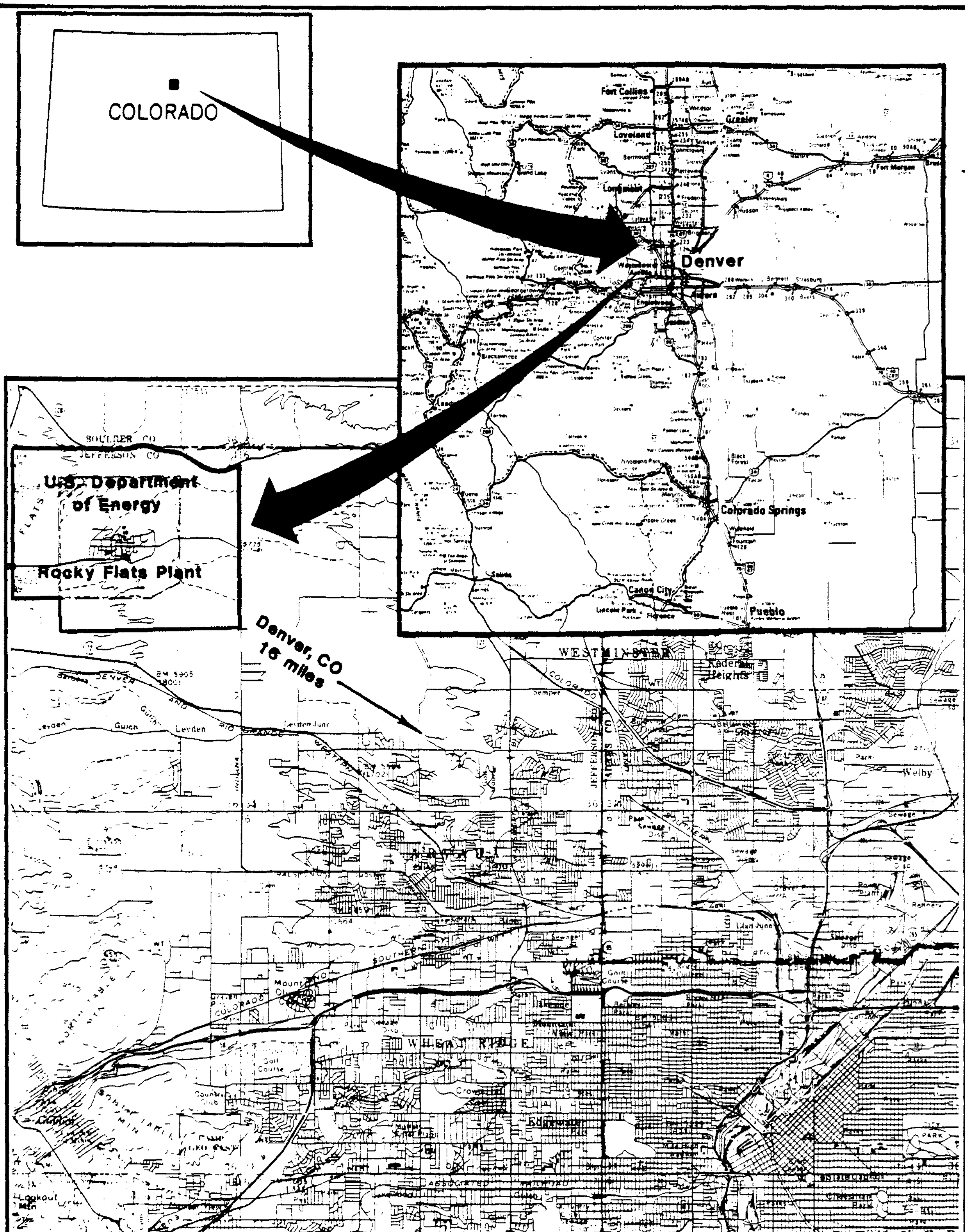
Presented in this introduction are site location and description, objectives of this study, and a summary of previous investigation results. The introduction is followed by a regional setting chapter (Section 3) which describes climatology, physiography, geology, ground-water hydrology, and surface water hydrology in the vicinity of Rocky Flats Plant. Section 4 describes the site hydrogeology, including site geologic setting, ground-water flow paths, and water quality. Section 5 characterizes the surface water pathway including descriptions of surface water flow and surface water chemistry.

Appendices A through D contain supporting data. The sampling plan for the 1987 field work is presented in Appendix A. Appendices B and C contain the hydrogeologic data and analytical data, respectively. Finally, Appendix D contains historical analytical data.

2.2 SITE LOCATION AND DESCRIPTION

The Rocky Flats Plant is located in northern Jefferson County, Colorado, approximately 16 miles northwest of Denver (Figure 2-1). The Plant consists of approximately 6,550 acres of federally owned land in Sections 1 through 4 and 9 through 15 of T2S, R70W, 6th Principal Meridian. Major buildings are located within the Plant security area of approximately 400 acres. The security area is surrounded by a buffer zone of approximately 6,150 acres (Figure 2-2).

This site characterization report addresses the Present Landfill located on the north side of the Rocky Flats Plant (Figure 2-2). This site was identified as a regulated unit because materials contaminated with listed hazardous wastes were disposed at the landfill.



Not To Scale

Figure 2-1: Location of Rocky Flats Plant

The Present Landfill was placed in operation on August 14, 1968 after a study determined that a landfill operation would be the most efficient and economical means to dispose of the Plant nonradioactive solid waste. A number of available sites within the Plant's boundaries were evaluated. The site selected is located on the western end of an unnamed tributary to North Walnut Creek. The west end of this unnamed tributary to North Walnut Creek was filled, with on-site soils from a borrow area, to a depth of 5 feet across the width of the channel. Aerial photographs from August, 1969, show that landfill operations had commenced by that time.

In 1974, the landfill had expanded in surface area to approximately 300,000 square feet. Two geotechnical studies were undertaken for the future expansion of the landfill including the construction of two pond embankments east of the landfill and ground-water, surface water, and leachate collection systems. The pond embankments and collections systems were constructed in 1974 (Figure 2-3).

The west pond (Pond No. 1) embankment was constructed approximately 500 feet east of the 1974 position of the landfill's advancing face. The east pond (Pond No. 2) embankment was constructed approximately 1,000 feet east of the west pond embankment. A cutoff trench, set in bedrock, was constructed in the east pond embankment to reduce seepage through the embankment foundation. The embankments and ponds were built to collect and evaporate ground water, surface water, and leachate from the collection systems.

The collection systems consist of a surface water interceptor ditch and a combined leachate and ground-water interceptor system. The surface water interceptor ditch was constructed around the exterior of the landfill to direct surface water run-off from outside of the ditch around the landfill. The ditch is V-shaped and approximately three feet deep with steep side slopes (Figure 2-4).

In 1977, another geotechnical study (Lord, 1977) was conducted for the expansion of the landfill and for the location of a new borrow area north of the landfill. The field investigation consisted of drilling seventeen test borings; ten at the proposed landfill extension site, five in the proposed borrow area, and two in the existing borrow area.

The west embankment and pond were removed in 1981 to allow eastward expansion of the landfill. Between 1977 and 1981, the leachate collection system was covered with waste as the landfill expanded beyond the limits of the system. Two slurry trenches were constructed in 1981 extending eastward from the ends of the north and south ground-water interceptor ditches. These slurry trenches vary in depth from 10 to 25 feet and were designed to be seated in bedrock. The leachate pond (Pond No. 1) can no longer be seen on aerial photographs beginning in the year 1982.

Since beginning operations in 1968, the landfill has occupied a total volume of approximately 120,000 cubic yards based on aerial photographs and geotechnical studies; (Colorado Aerial Photo Service 1968, 1970, 1972, 1974-1985; U. S. Geol. Survey, 1971; Scharf & Assoc., 1986; Agricultural Stabilization and Conservation Service, 1969; Woodward-Clevenger, 1974; Zeff et al., 1974; and Lord, 1977). Of the 120,000 cubic yards, approximately 17,000 cubic yards are estimated to be soil utilized as cover. The volume of covers is based on two 6-inch layers extending over an area approximately 230,000 square feet. The total volume, as of November 1986, of compacted waste was estimated to be 103,000 cubic yards (Rockwell International, 1986a).

2.3 OBJECTIVES

The objectives of this study are to characterize site geology, hydrology, and the extent of contamination. This information will be used to support closure activities and develop post closure care and monitoring programs. Post closure care activities and monitoring programs are presented in the Post Closure Care Permit Application. Specifically, it is the objective of this study to evaluate the effectiveness of the ground-water intercept system, the leachate collection system, and the slurry trenches. In addition, an evaluation of the ground-water quality and hydrogeology are presented along with recommendations for additional field work.

2.4 SUMMARY OF PREVIOUS INVESTIGATIONS

A series of investigations have been conducted at the Plant to characterize ground water, surface water, and soils. A summary of investigations performed at the Present Landfill is presented below.

Two geotechnical investigations (Woodward-Clevenger, 1974; and Zeff et al., 1974) were conducted for the 1974 expansion of the Present Landfill. Woodward-Clevenger drilled 47 test holes in the existing landfill. In addition, a total of six boreholes were drilled in three other sites to examine their suitability for landfill construction. The study concluded that all but one location was acceptable for landfill expansion/construction and that a ground-water monitoring system should be installed.

The geotechnical investigation undertaken by Zeff et al., (1974) proposed renovation plans for the existing landfill. Plans were developed to construct an impervious ring around the landfill to intercept and divert ground and surface water away from the landfill. In addition, structures were designed to sample and impound all drainage effluent from the landfill. The Zeff et al. (1974) proposals were implemented in 1974.

Another geotechnical study was conducted in 1977 by Lord and Associates. This report discussed the suitability of the claystone bedrock to serve as the landfill liner. The claystone bedrock was determined adequate to serve as a liner, and the overburden materials were determined adequate for daily landfill cover.

Hydro-Search, Inc. (1985) presented a hydrogeologic characterization of the Rocky Flats Plant. This report describes the hydrogeologic and ground-water quality conditions at the Plant based on data existing at the time. The ground-water monitoring system was described and evaluated, and recommendations were made for a new monitoring program.

In 1986, R.L. Henry (Rockwell International) submitted a report summarizing trends observed in the surface water monitoring at Rocky Flats Plant. The report discusses the surface water control system (SWCS) completed in 1980, which is designed to divert flow around Plant site and collect surface runoff and store it temporarily for monitoring before discharge. Henry also discusses non-radioactive and radioactive trends in the surface water quality.

Chen and Associates (Rockwell International, 1986a) prepared a closure plan for the Present Landfill at Rocky Flats Plant. This plan describes the construction and operation procedures at the landfill including disposal policies and procedures;

the leachate collection system; waste inventory; treatment and disposal of solid waste and hazardous waste; and collection, removal, and treatment of leachate.

Chen and Associates (Rockwell International, 1986b) also prepared a preliminary prioritization of sites at Rocky Flats Plant. The prioritization of sites was based on review of previous investigations and historical aerial photographs. The Present Landfill was considered a priority site at that time.

Four ground-water monitoring wells, two upgradient and two downgradient of the landfill, were installed in 1986 according to the procedures outlined in Rockwell International (1986c). These wells were installed to characterize the hydrogeology in the vicinity of the landfill and to evaluate whether the landfill pond was an imminent threat to the public or the environment. The work plan for the 1986 field program is presented in Rockwell International (1986d), and Plate 2-1 presents monitor well locations at Rocky Flats Plant.

Tracer Research (1986) conducted a shallow soil-gas investigation at the Rocky Flats Plant. Ninety-five soil-gas and shallow ground-water samples were collected and analyzed. Another soil-gas survey was performed in 1987 by Chen and Associates using the Petrex method. Two grids were set up around the Present Landfill on 120 foot centers. A total of 140 samples were collected from these areas.

In 1987, seventeen additional ground-water monitoring wells were installed for characterization of the Present Landfill. Sixteen alluvial wells and one bedrock well were installed.

Rockwell International (1975, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986e, and 1987a) are annual environmental monitoring reports. These reports summarize annual monitoring, data collection, analyses, and evaluations of programs at the facility.

SECTION 3

REGIONAL SETTING

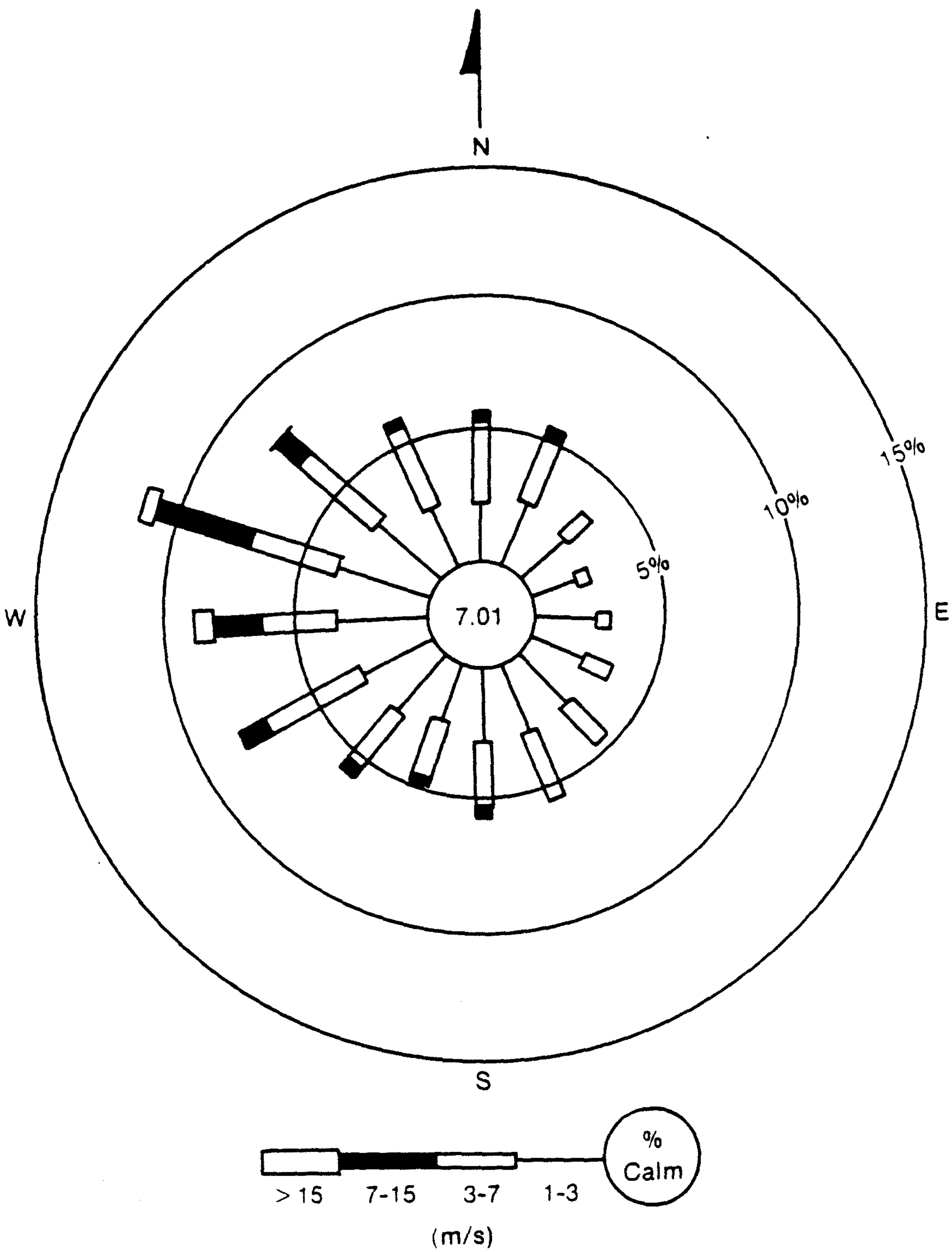
This section presents the regional setting of Rocky Flats Plant, including discussions of climatology, physiography, geology, ground-water hydrology, and surface water hydrology. Site-specific discussions of hydrogeology and surface water hydrology at the Present Landfill are presented in Sections 4.0 and 5.0, respectively.

3.1 CLIMATOLOGY

The area surrounding the Rocky Flats Plant has a semiarid climate typical of the Rocky Mountain region. However, the elevation of the Plant and the nearby slopes of the Front Range slightly modify the regional climate.

Winds at Rocky Flats Plant, although variable, are predominantly from the west-northwest. Stronger winds occur during the winter, and the area occasionally experiences Chinook winds with gusts up to 100 miles per hour because of its location near the Front Range (DOE, 1980). Figure 3-1 shows the wind direction, frequency, and average velocity for each direction as recorded in 1985.

Temperatures are moderate; extremely warm or cold weather is usually of short duration. On the average, daily summer temperatures range from 55 to 85 degrees Fahrenheit (F) and winter temperatures range from 20 to 45 degrees F. Temperature extremes recorded at the Plant have ranged from 102 degrees F on July 12, 1971 to -26 degrees F on January 12, 1963. The 24-year daily average maximum temperature for the period 1952 to 1976 was 76 degrees F, the daily average minimum



(after: Rockwell International, 1987a)

Figure 3-1:

1986 Annual Wind Rose for the Rocky Flats Plant

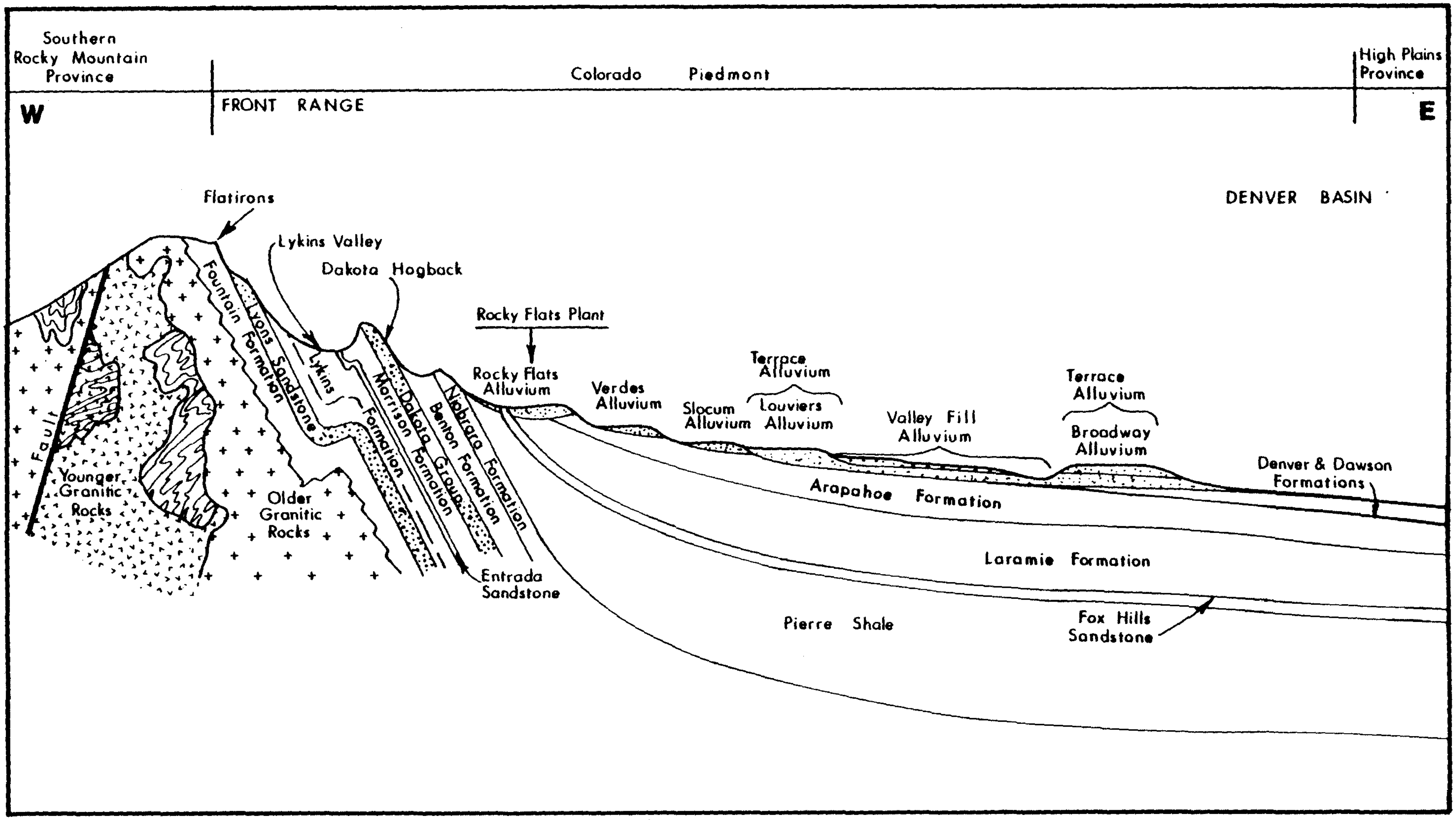
was 22 degrees F, and the average annual mean was 50 degrees F. Average relative humidity was 46 percent (DOE, 1980).

Average annual precipitation at the Plant is 15 inches. Approximately 40 percent of the precipitation falls during the spring season, much of it as snow. Thunderstorms from June to August account for an additional 30 percent of the precipitation. Autumn and winter are drier seasons, accounting for 19 and 11 percent of the annual precipitation, respectively. Snowfall averages 85 inches per year, generally occurring between October and May (DOE, 1980).

3.2 PHYSIOGRAPHY

The Rocky Flats Plant is located at an elevation of approximately 6,000 feet above mean sea level. The site is on the western margin of the Colorado Piedmont section of the Great Plains Physiographic Province (Fenneman, 1931). The Colorado Piedmont ranges in elevation from 4,000 feet on the east to 7,000 feet on the west. The Piedmont merges to the east with the High Plains section of the Great Plains Province and is terminated abruptly on the west by the Front Range section of the Southern Rocky Mountain Province (Figure 3-2).

The Colorado Piedmont is an area of dissected topography and denudation where Tertiary strata underlying the High Plains have been almost completely removed. In a regional context, the piedmont represents an old erosional surface along the eastern margin of the Rocky Mountains. It is underlain by gently dipping sedimentary rocks (Paleozoic to Cenozoic in age), which are abruptly upturned at the Front Range to form hogback ridges parallel to the mountain front. The piedmont surface is broadly rolling and slopes gently to the east with a topographic relief of



(after: Boulder County Planning Commission, 1983 and Scott, 1960)

Not To Scale

Figure 3-2:
Generalized East-West Cross Section
Front Range to Denver Basin

only several hundred feet. This relief is due both to resistant bedrock units that locally rise above the surrounding landscape and to the presence of incised stream valleys. Major stream valleys which transect the piedmont from west to east have their origin in the Front Range. Small local valleys have developed as tributaries to these major streams within the piedmont. In the area of the Plant, a series of Quaternary pediments have been eroded across this gently rolling surface (DOE, 1980).

The eastern margin of the Front Range a few miles west of the Plant is characterized by a narrow zone of hogback ridges and flatirons formed by steeply east-dipping Mesozoic strata (such as the Dakota Sandstone and the Fountain Formation). Less resistant sedimentary units were removed by erosion (Figure 3-2). The Front Range reaches elevations of 12,000 to 14,000 feet above mean sea level 15 miles farther west. The range itself is broad and underlain by resistant gneiss, schist and granitic rocks of Precambrian age. The resistant nature of these rocks has restricted stream erosion so that deep, narrow canyons have developed in the Front Range.

Several pediments have been eroded across both hard and soft bedrock in the area of the Plant during Quaternary time (Scott, 1963). The Rocky Flats pediment is the most extensive of these, forming a broad flat surface south of Coal Creek. The broad pediments and more narrow terraces are covered by thin alluvial deposits of ancient streams draining eastward into the Great Plains. The sequence of pediments reflects repetitive physical processes associated with cyclic changes in climate. Each erosional surface and stratigraphic sequence deposited on it probably represents a single glacial cycle. The oldest and highest pediment, the Subsummit Surface (Scott, 1960), truncates the hogback ridges of the Front Range. Three successively younger pediments, veneered by alluvial gravels, extend eastward from the mountain front. Erosion of valleys into the pediments followed each depositional cycle so that, near the mountain front, stratigraphically younger geologic units occur at topographically lower elevations as narrow terrace deposits along the streams. From oldest to youngest, the three pre-Wisconsin deposits are the Rocky Flats Alluvium, the Verdos Alluvium and the Slocum Alluvium (Scott, 1965). A series of Wisconsin and post-Wisconsin terrace deposits are present at lower elevations along streams that have incised the older pediments (east of the Plant). These alluvial deposits are described in Section 3.3.3, Surficial Geology.

The Rocky Flats Plant is located on a relatively flat surface of Rocky Flats Alluvium. The pediment surface and overlying alluvium (generally 10 to 50 feet thick, although the alluvium is as much as 100 feet thick west of the Plant) have been eroded by Walnut Creek on the north and Woman Creek on the south so that terraces along these streams range in height from 50 to 150 feet. The grade of the gently eastward-sloping, dissected Rocky Flats Alluvium surface varies from 0.7 percent at the Plant to approximately 2 percent just east of the Plant.

3.3 REGIONAL GEOLOGY

3.3.1 Geologic and Stratigraphic History

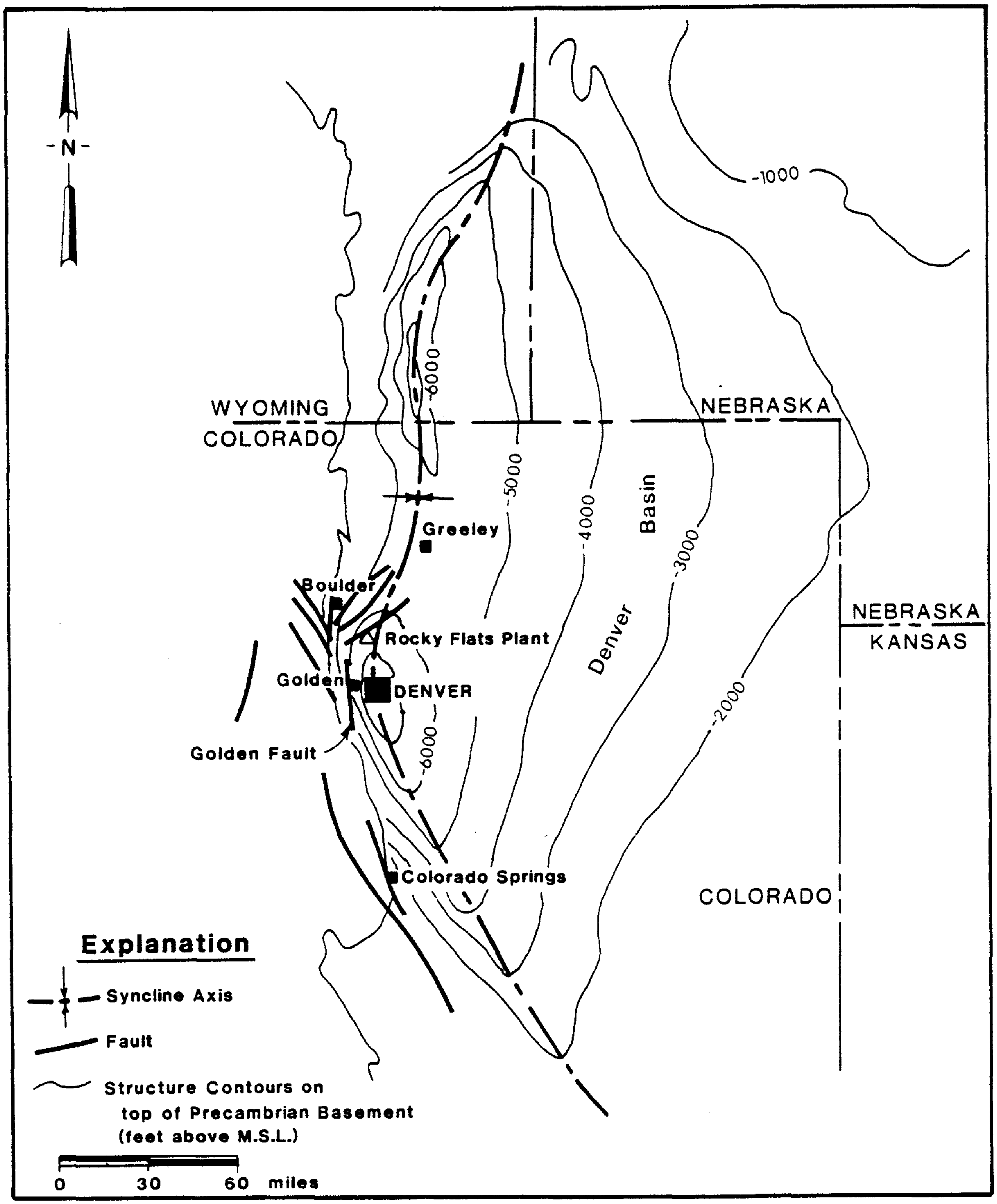
This section describes the regional geologic and stratigraphic history in the vicinity of the Plant, including the Denver Basin. Section 4.0 describes the site specific geology and stratigraphy of the Present Landfill.

The Rocky Flats Plant is located on the northwestern flank of the Denver Basin and is underlain by about 12,000 feet of Paleozoic and Mesozoic sedimentary rocks (Hurr, 1976). The Denver Basin is an asymmetric syncline that formed during the Late Cretaceous Laramide Orogeny. The western limb of the basin dips steeply to the east, and the eastern limb dips gently to the west (Figure 3-3).

The geologic history of northeastern Colorado involves several episodes of mountain building and oceanic transgression and regression, resulting in the deposition of thousands of feet of sedimentary rock on top of the Precambrian basement. This section describes the geologic history beginning with Precambrian time. Geologic descriptions of the various units are provided within this context. More detailed descriptions of the units present on site are provided in Section 5.0.

Early Precambrian tectonic, metamorphic, and plutonic igneous activity created a complex fabric in the basement rock of Colorado (Grose, 1972). The Precambrian units were covered by marine and continental sedimentation during the lower Paleozoic (carbonate and siliciclastic rock units were deposited unconformably on the Precambrian basement). Most of these units were later eroded by multiple Paleozoic diastrophisms, thus removing Cambrian to Mississippian rocks from the Denver Basin area (Kent, 1972).

Middle Pennsylvanian orogenic activity formed the Ancestral Rockies, and the Fountain Formation was deposited unconformably on the uplifted Precambrian basement (Figure 3-4). The Fountain Formation contains coarse clastics derived from the erosion of the Ancestral Rockies and deposited as alluvial fans along a continental margin (Martin, 1965). The result was nonmarine sedimentation that occurred in northeastern Colorado from the Triassic to early Cretaceous. This sedimentation deposited a sequence of aeolian, fluvial-deltaic, and lacustrine units



(after: Rockwell International, 1986a)

Figure 3-3: Structure of the Denver Basin

AGE	FORMATION	Thick. (feet)	SUMMARY DESCRIPTION
TERTIARY	Green Mountain	600'	Boulder conglomerate with occasional thin siltstone lenses
TERTIARY / UPPER CRETACEOUS	Denver-Arapahoe	1200'	Tan sandy claystone and clayey sandstone; conglomerate at base; includes Table Mountain "flow" rocks to the north
UPPER CRETACEOUS	Laramie	500'	Gray, fine-to-medium-grained sandstone and silty clays; thin coal beds in lower part
UPPER CRETACEOUS	Fox Hills	50'	Tan, fine-to-medium-grained sandstone and sandy shale
UPPER CRETACEOUS	Pierre	± 8000'	Dark gray, silty shale and few thin, silty sandstones
UPPER CRETACEOUS	Niobrara	350'	Dark gray, very calcareous shale. "Foraminifers" abundant (Smoky Hills Member) Light gray, dense, fossiliferous limestone (Fort Hays Member)
UPPER CRETACEOUS	Benton	420'	Brown, sandy, fossiliferous limestone Dark gray shale with bentonite streaks; thin limestones in middle part; few cone-in-cone concretions in lower part Dark gray, brittle silty shale (Mowry)
LOWER CRETACEOUS	Dakota Group: So. Platte	270'	Light gray, fine-to-medium-grained sandstone, several dark gray shales in middle part
LOWER CRETACEOUS	Dakota Group: Lytle	100'	Light gray, fine-to-coarse-grained, locally conglomeratic sandstone; frequent red and green siltstone interbeds
Jurassic	Morrison	365'	Gray to greenish-gray to red shale and siltstone; thin limestones in middle part; lenticular sandstones in upper and lower part
Jurassic	Ralston Creek	110'	Light tan siltstone and light red; silty shale; gypsiferous; sandstone at base and locally conglomeratic
Tri-assic? / PERMIAN	Lykins	400'	Red siltstone with two laminated limestones in lower part
PERMIAN	Lyons	120'	Grayish-white, fine-to-medium-grained cross-bedded sandstone; conglomeratic lenses frequent
PENNSYLVANIAN	Fountain	1000'	Red, fine-to-coarse-grained sandstone and conglomerate; arkosic; thin, lenticular red siltstones frequent throughout
PRECAMBRIAN			Gneiss, schist, and small granitic intrusions

Figure 3-4: Generalized Stratigraphic Section, Golden-Morrison Area

(after: LeRoy and Weimer, 1971)

known as the Lyons, Lykins, Ralston Creek, Morrison, and Dakota Formations (Figure 3-4) (Kent, 1972).

The Pierre Shale, consisting of more than 5,600 feet of shales and siltstones, was deposited in the final phases of oceanic sedimentation. The sedimentation resulted from the last oceanic transgression occurring 100 million years ago during the late Cretaceous. This transgression formed an epicontinental sea called the Cretaceous Seaway that covered the eastern portions of New Mexico, Colorado, and Wyoming.

Following deposition of the Pierre, the ocean began to regress and deposition of the Upper Cretaceous Fox Hills and Laramie Formations occurred. These formations contain sandstones, siltstones, claystones, and coals deposited in fluvial-deltaic and lacustrine environments (Weimer, 1973). Deposition of the Laramie was influenced and then stopped by the Laramide Orogeny, a major mountain building event that began in the late Cretaceous and caused uplift of the Colorado Front Range Mountains and the eastward tilting of the Denver Basin.

The Upper Cretaceous Arapahoe Formation was deposited on an erosional surface marking the end of deposition of the Laramie. Major uplift of the Front Range and downwarp of the Denver Basin continued during deposition of the Arapahoe Formation. Coarse pebble conglomerate lenses deposited in alluvial fans commonly occur in the Lower Arapahoe; however, conglomerate lenses have not been found at Rocky Flats Plant. Claystone and sandstone units flank and top the alluvial fan deposits (Weimer, 1973).

The Denver Formation was deposited above the Arapahoe and is over 600 feet thick. This formation contains a variety of lithologies including siltstones, arkoses, conglomerates, and basalt flows (near Golden, Colorado) (Robson, 1984).

The Dawson Formation was deposited above the Denver in a similar geologic environment during the late Cretaceous and early Tertiary. Robinson (1972) described the Dawson Formation as a stratigraphic equivalent to the Denver Formation in southern portions of the Denver Basin. However, Robson (1984) mapped the Dawson as a separate, younger (Tertiary) formation occurring above the Denver. The Dawson is up to 600 feet thick and consists of conglomerates, sandstones, and shales (Robson, 1984).

The Tertiary Green Mountain Conglomerate was deposited unconformably on the Denver Formation, and consists of conglomerates, sandstones, siltstones, and claystones deposited by a local fluvial system that occurred only in the Golden, Colorado, area. This unit is only found capping Green Mountain, approximately 15 miles south of Rocky Flats Plant (Costa and Bilodeau, 1982).

The Rocky Flats Alluvium was deposited on top of a major erosional surface that developed in late Tertiary time. Before deposition of the Rocky Flats Alluvium, both the Dawson and Denver Formations were completely removed by erosion. The Green Mountain Conglomerate may never have been deposited at the site, but if it was, it also was removed by erosion. The Rocky Flats Alluvium contains boulders, cobbles, gravels, sands, silts, and clays deposited in alluvial fans at the base of the Colorado Front Range Mountains (Hurr, 1976).

Following deposition of the Rocky Flats Alluvium, the material was partially removed by erosion and the resulting drainages repeatedly infilled with more recent sediments. The Verdos Alluvium and the younger Slocum Alluvium are the result of drainage infilling associated with glacial activity. Similar processes are occurring now with an active valley fill alluvium in the stream channels and a recent but stable terrace above the valley fill.

3.3.2 Plant Bedrock Geology

Bedrock units mapped at the Plant consist of the Laramie and Arapahoe Formations (Rockwell International, 1986a). These are shown in cross section in Figure 3-5. Because of the thickness (750 to 800 feet) and low permeability of the Upper Laramie, it is considered to be the base of the hydrologic system which could be affected by Plant operations (Hurr, 1976). The Upper Laramie and overlying Arapahoe Formations are described below.

Laramie Formation

The Laramie Formation is a fluvial sequence of sandstones, siltstones, claystones, and coals, which is subdivided into two major lithologic units: a lower sandstone unit and an upper claystone unit. The lower sandstone unit is exposed in clay pits west of the Plant, and the upper claystone unit was observed in outcrop and in cores of several 1986 monitor wells west of the Plant. The descriptions presented below are taken from Rockwell International (1986a).

Lower Sandstone Unit: The lower sandstone unit consists of light to medium gray, very fine- to medium-grained, well sorted, subrounded to subangular quartzose sand with up to 25% lithic fragments. Sandstones are typically fair to poorly

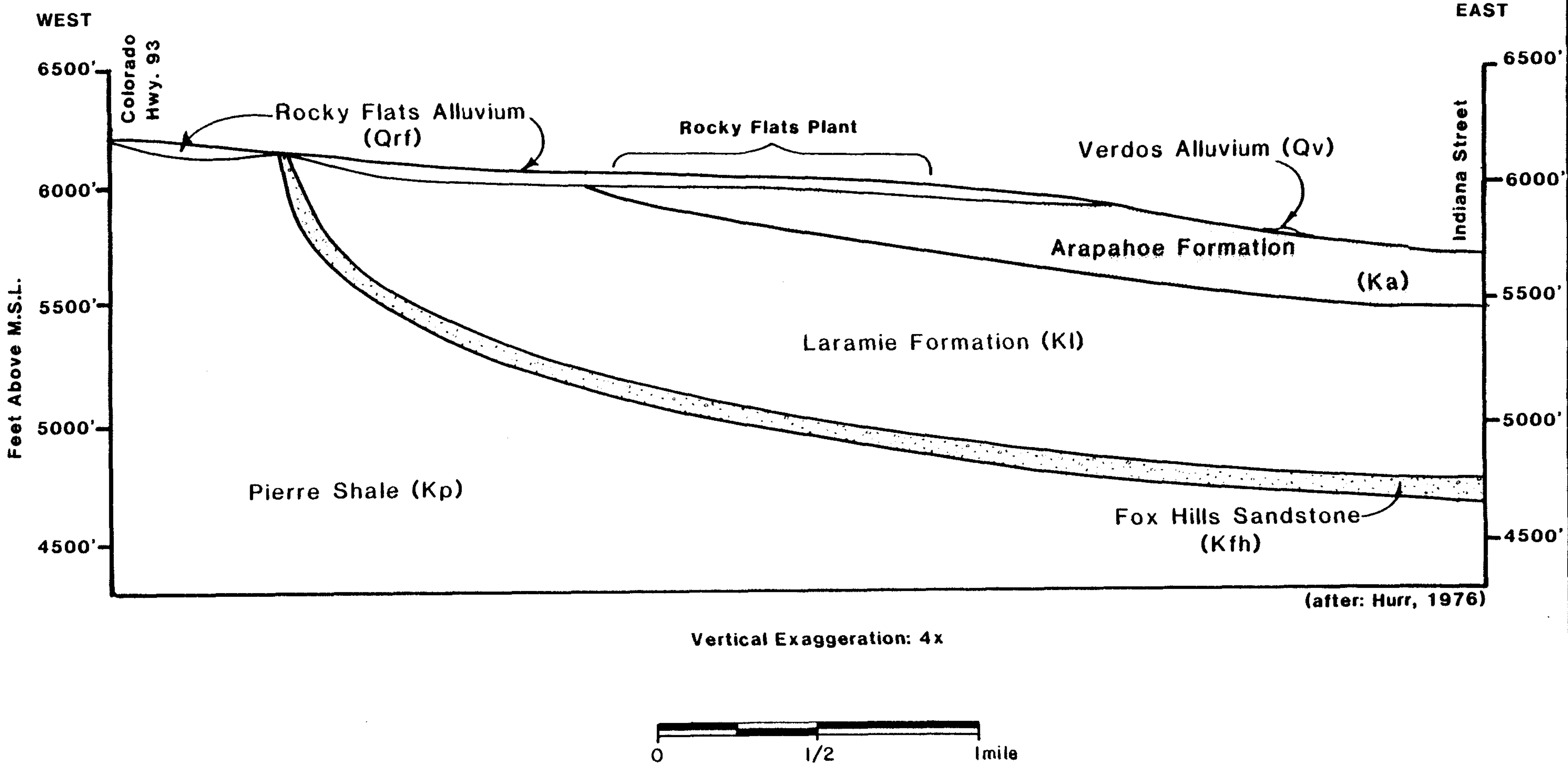


Figure 3-5: **Generalized Cross Section of Rocky Flats Plant**

indurated and cemented with silica. Individual sandstone beds are 5 to 15 feet thick and are interbedded with white to light gray claystones. The claystones are organic-rich and kaolinitic and have been mined from the clay pits west of the plant. Individual claystone beds are 10 to 15 feet thick. Sedimentary structures observed in outcrop include planar, angular, and trough crossbeds, load structures, fluid escape structures, and ripple marks. Plant fossil casts and molds of branches, stems, and leaves are concentrated along bedding planes. The contact between the lower sandstone unit and the upper claystone unit is gradational and was selected where thick sandstone beds and kaolinite-rich claystones are less abundant.

Upper Claystone Unit: The upper claystone unit consists primarily of dark olive gray (5 Y 2/1) (GSA Rock Color Chart), poorly indurated claystones. Upper Laramie claystones generally weather to a light olive gray (5 Y 4/1) and may have dark yellowish orange (10 YR 6/6) iron staining along bedding planes and secondary fractures. These claystones appear quite similar to Arapahoe claystones in outcrop.

Thin sandstone lenses (less than three feet thick) also occur in the upper Laramie. These sandstones are typically yellowish gray (5 Y 8/1), fine- to very fine-grained, well sorted, subangular, and calcareous. Core data (well 50-86) indicate that thin beds of white, kaolinite-rich claystone typical of the Lower Laramie occur in the Upper Laramie as well.

The contact between the Upper Laramie claystones and the Lower Arapahoe sandstones is gradational and was selected using core data. The contact was picked below the first Arapahoe sandstone greater than five feet thick (Rockwell

International, 1986a). This is consistent with the stratigraphic horizon picked as the base of the Arapahoe Formation at Rocky Flats Plant by Hurr (1976, 1985).

Arapahoe Formation

The Arapahoe Formation consists of fluvial claystones with interbedded lenticular sandstones and siltstones. Contacts between these lithologies are both sharp and gradational. The claystones are olive gray (5 Y3/2) to dark gray (N 3/0), poorly indurated, silty, and contain up to 15 percent organic material. Weathering has penetrated from 10 to 40 feet into bedrock. The weathered claystone is light olive gray, blocky, slightly fractured, and has iron staining as mottles and along bedding planes and fractures (Rockwell International, 1986a).

Sandstones in the Arapahoe Formation are light gray (N 6/0) to yellowish gray (5 YR 8/1), very fine- to medium-grained, with approximately 15 percent silt and clay. The sandstones are lenticular, discontinuous, and stratigraphically complex. The sand grains are subangular to subrounded and are predominantly quartzose with 10 percent lithic fragments. The sandstones are poorly to moderately cemented and exhibit ripple marks, load casts, and planar, angular, and trough crossbedding. Arapahoe Formation siltstones exhibit the same coloration, constituents, bedding characteristics, and sedimentary structures as the sandstones; however, they consist predominantly of silt-sized particles (Rockwell International, 1986a).

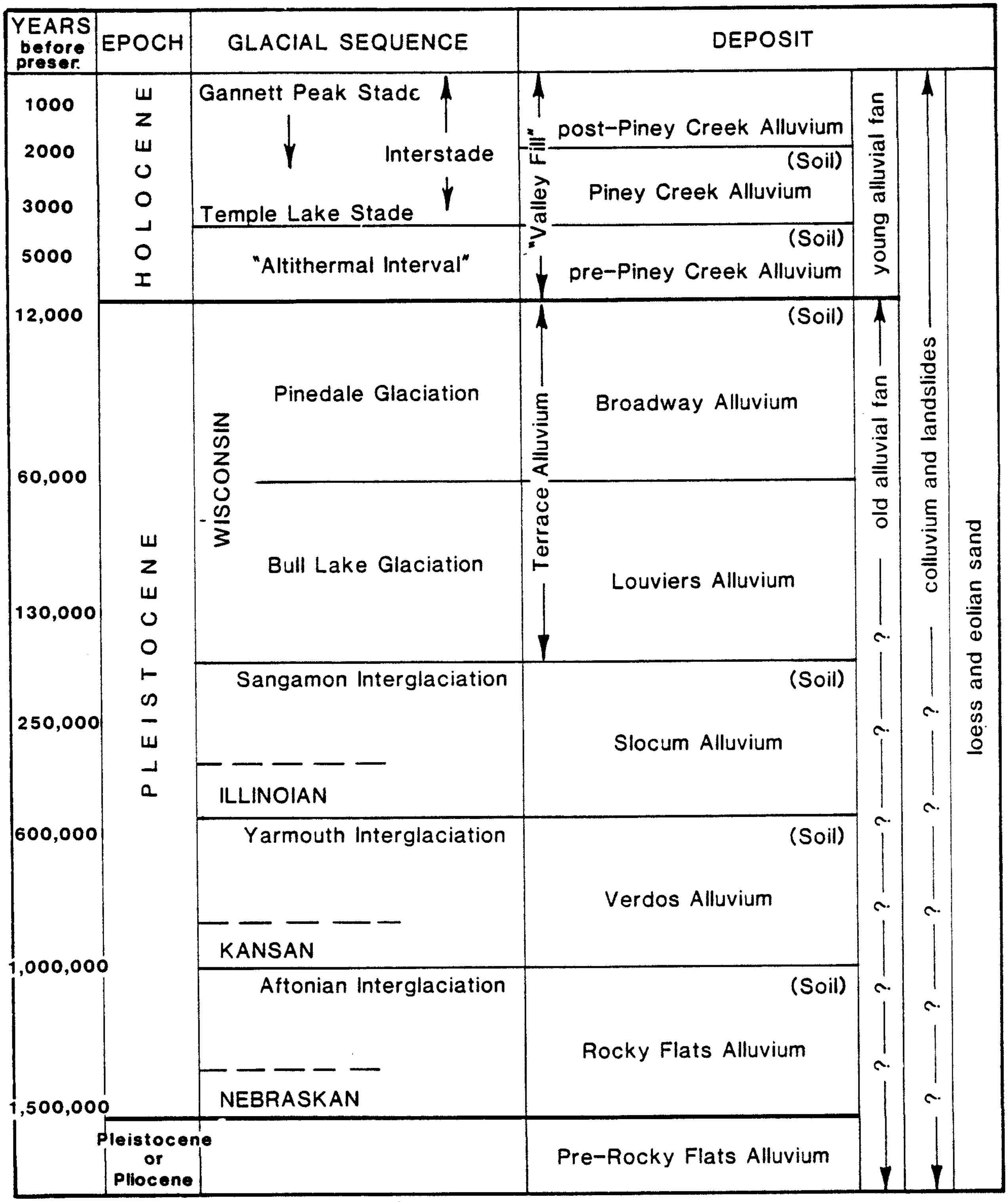
3.3.3 Plant Surficial Geology

There are six distinct Quaternary unconsolidated units of surficial materials in the vicinity of the Plant: Rocky Flats Alluvium, Verdos Alluvium, Slocum Alluvium, terrace alluviums, valley fill alluvium, and colluvium (Figure 3-6).

The Rocky Flats Alluvium is topographically the highest and the oldest of the alluvial deposits. The alluvium unconformably overlies the Laramie and Arapahoe Formations in the vicinity of the Plant. The deposit is a series of laterally coalescing alluvial fans deposited by streams (Hurr, 1976). The fans were deposited on an erosional surface cut into the bedrock units, including channelization around the hogbacks of the lower Laramie.

The alluvium consists of sand, clay, silt, gravel, cobble, and occasional boulder deposits. Locally, the alluvium is cemented with calcium carbonate in the form of caliche. Color of the alluvium is pale to dark yellowish brown. The sands range from very fine-grained to medium-grained and poorly to moderately sorted. The thickness of the alluvium is variable due to deposition on an erosional surface and recent erosional processes. The alluvium is thickest to the west of the Plant, where less has been eroded, and thinnest to the east of the Plant (Rockwell International, 1986a).

Various alluvial deposits occur topographically below the Rocky Flats Alluvium in the drainages and include the Verdos, Slocum, terrace, and valley fill alluviums and colluvium (Figure 3-7). These deposits are primarily composed of reworked Rocky Flats Alluvium with the addition of some bedrock material. Each unit is described below.



(after: Van Horn, 1976, and Scott, 1965)

Figure 3-6:
Surficial Alluvial Deposits in the Rocky Flats Area

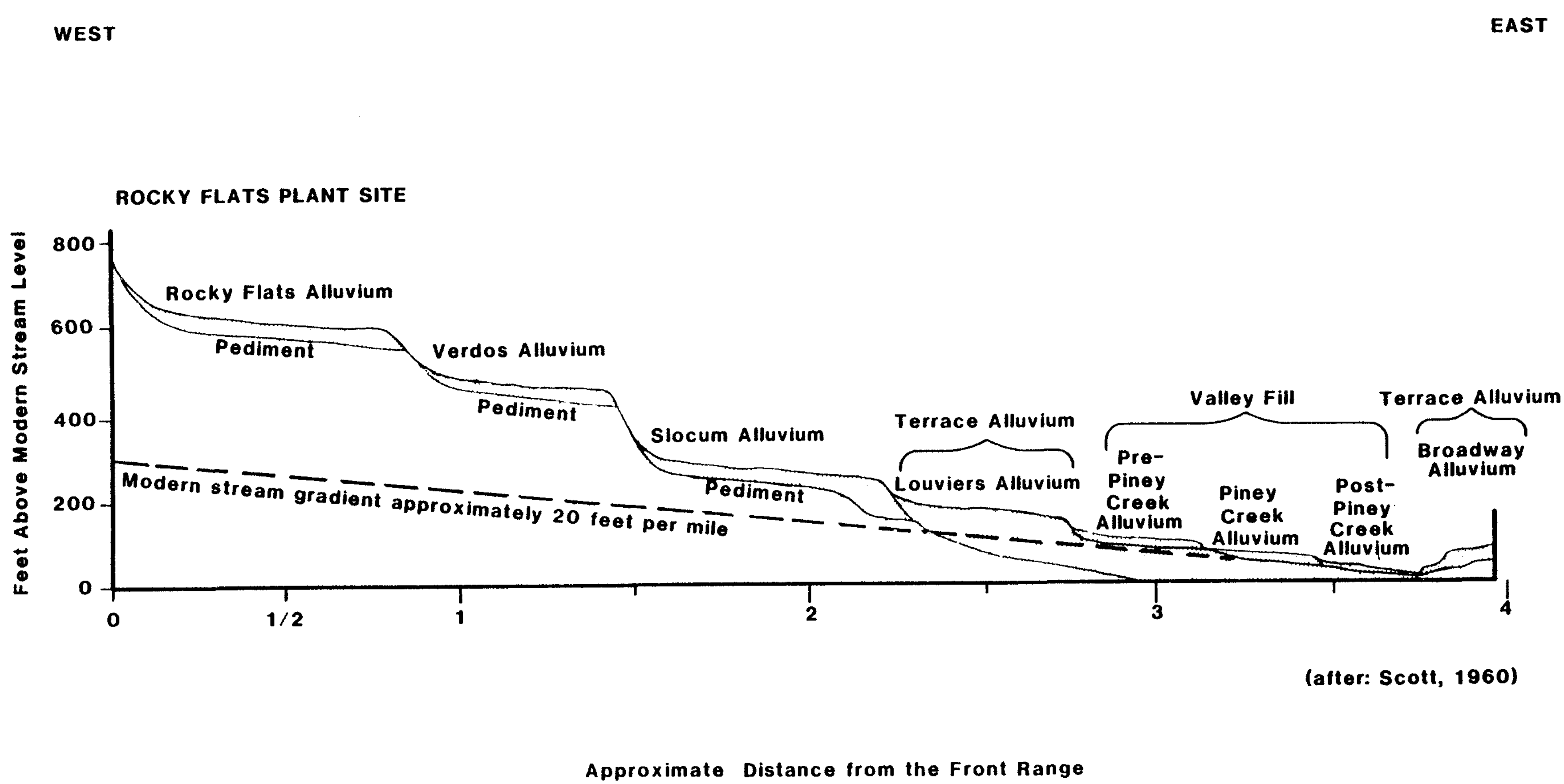


Figure 3-7:
Erosional Surfaces and Alluvial Deposits East of the Front Range, Colorado

The Verdos Alluvium occupies a topographic position about 0 to 100 feet below the adjacent top of the Rocky Flats Alluvium. The Verdos was deposited around the periphery of the present extent of the Rocky Flats Alluvium as fans and channel filling derived by erosion of the older Rocky Flats Alluvium. The maximum thickness is about 40 feet, occurring as terraces in valleys east of the Plant. The alluvium consists of unsorted gravels, sands, and clays similar to the Rocky Flats Alluvium, but the material is whitish gray in color (Rockwell International, 1986a).

The Slocum Alluvium is a poorly sorted gravel deposit containing much sand, silt, and clay derived from erosion of bedrock and the older gravel deposits. The formation has a maximum thickness in the vicinity of the Plant of about 20 feet, but is commonly 5 to 10 feet thick. It occupies a topographic position of about 150 to 300 feet below the top of the Rocky Flats Alluvium, and occurs downslope of the Verdos Alluvium in valleys east of the Plant site (Rockwell International, 1986a).

Locally, two Wisconsin-age terraces are associated with the present drainages. The terrace alluvium occurs 5 to 35 feet above recent valley floors. The alluvium is comprised of gravels, sands, and clays, derived from bedrock and reworking of older alluvial deposits. The terrace alluvium can rarely occur up to 30 feet in thickness; however, the thickness is usually around 5 feet. The alluvium occurs in valleys surrounding the Plant (Rockwell International, 1986a).

Valley fill alluvium occurs in the bottom of the present stream valleys around the Plant. The valley fill ranges from dark-brown, sandy, clayey silt to moderately sorted cobbles and small boulders, recently reworked from previously deposited alluviums. The valley fill along streams which head on the Rocky Flats Alluvium and have not yet cut through to bedrock tends to be coarse and have little or no fine material. However, where the valley fill is deposited on bedrock, 0.5 to 2 feet of cobbly sand and gravel commonly is overlain by several feet of sandy, clayey silt (Rockwell International, 1986a). Subsequent erosion and deposition locally may have added more sand, gravel and cobbles on top of the silt, or cut through the valley fill to expose bedrock along the channel bottom (Hurr, 1976).

Colluvium, produced by mass wasting and downslope creep, collects on the sides and at the base of hills and slopes. These deposits are poorly sorted mixtures of soil and debris from bedrock clay and sand mixed with gravel and cobbles derived from the older Rocky Flats Alluvium. The colluvium consists predominantly of clay with common occurrences of sandy clay and gravel. Color is yellowish brown to dusky brown and caliche is common locally. The thickness of the colluvium ranges from 3 to 22 feet (Rockwell International, 1986a).

3.3.4 Regional Bedrock Structure

The general geologic structure of the area is north-striking sedimentary beds with dips to the east away from the Front Range Monocline. Dips are quite steep west of the Plant in the Fox Hills Sandstone and Laramie Formation (on the order of 50 degrees or greater). These units are flanked on the west by Precambrian terrain of the Front Range Uplift and on the east by gently dipping sedimentary beds of the Denver Basin. However, because the axis of the monocline onto the Front Range appears to be inclined to the east, dips become rapidly more gentle, on the order of 7 to 15 degrees beneath the Plant itself (Rockwell International, 1986a). A major bounding fault between the Front Range and the Denver Basin, the Golden Fault, runs north-south several miles west of the Plant at the mountain front (Figure 3-7).

The majority of the displacement on the Golden Fault, the uplift of the Front Range and subsidence of the Denver Basin, occurred during the late Cretaceous to early Eocene Laramide Orogeny about 40 to 70 million years ago (Martin, 1965). Erosion during the Laramide Orogeny is believed to have kept pace with uplift and the Front Range probably never stood very high above the Denver Basin during the orogeny. By the late Eocene, an erosional surface of the low relief covered much of the Rocky Mountain Region.

The present rugged topography to the west of the Rocky Flats Plant is the result of Post-Laramide tectonics and erosion. About 5,000 to 10,000 feet of uplift has taken place in the Rocky Mountain Region since the early Miocene about 25 million years ago. Late Tertiary block faulting is believed to have accompanied the regional uplift as indicated by apparent displacements of the late Eocene erosional surface (Scott, 1975 and Epis and Chapin, 1975). There is some evidence that block faulting has continued into the Quaternary (Scott, 1970; Whitkind, 1976; and Kirkham and Rogers, 1981).

In 1981, extensive studies were done to evaluate the Quaternary history of the Golden Fault and other faults at the Rocky Flats Plant and vicinity (Dames and Moore, 1981). The Golden Fault studies did not produce any evidence of tectonic activity along the Golden Fault within the past 500,000 years, and the fault does not have surficial expressions characteristic of geologically young fault zones.

Hurr (1976) showed a fault crossing the eastern edge of the Plant, based on a series of bedding irregularities that appeared to be an extension of the previously mapped Eggleston Fault (northwest of the site). Further investigations of the feature (Dames and Moore, 1981) revealed that it is probably a penecontemporaneous growth fault attributed to slumping of the unconsolidated Arapahoe Formation before burial and lithification. The Denver Basin has been tectonically stable for about 28 million years with the exception of a series of earthquakes associated with waste injection at the Rocky Mountain Arsenal in the 1960s and possible surface rupture on the Golden Fault approximately 600,000 years ago (Kirkham and Rogers, 1981).

3.4 REGIONAL GROUND-WATER HYDROLOGY

There are two hydraulically connected ground-water systems at the Rocky Flats Plant. These systems occur in the surficial material (Rocky Flats Alluvium, colluvium, and valley fill material) and the underlying bedrock formations (Laramie-Fox Hills Aquifer and the Arapahoe Aquifer). These are discussed individually below.

3.4.1 Unconfined Surficial Flow Systems

Recharge/Discharge Conditions

The shallow ground-water flow system occurs in the Rocky Flats Alluvium and other surficial materials under unconfined conditions. The alluvium is recharged by infiltration of incident precipitation, irrigation, and surface water diversion canals (primarily through the Rocky Flats Alluvium). In addition, the retention ponds in the various drainages recharge the valley fill alluvium.

The shallow system appears to be quite dynamic, with large water level changes in response to seasonal and other stresses. Hurr (1976) describes the rapid response of water levels in wells completed in the Rocky Flats Alluvium to surface flows in the irrigation ditches. Similarly, between mid-April and September 1986, the water levels in wells 1-86 and 4-86 at the eastern property boundary (completed in most recent valley fill) dropped more than four to eight feet, respectively. These wells were dry in September, and there was no water exiting the Plant as ground-water flow in the valley fill alluvium in either Woman or Walnut Creek.

Ground-Water Flow Directions

Flow directions follow topography to the east and toward the drainages. In addition, flow directions are controlled by the configuration of the top of bedrock beneath surficial materials. The ground water in the drainages flows to the east in the valley fill materials and discharges as subsurface flow across the eastern Plant boundary during some portions of the year. In addition, water in all of the surficial materials recharges the bedrock.

3.4.2 Bedrock Flow Systems

The Denver ground-water basin underlies a 6,700 square mile area extending from the Front Range on the west to near Limon, Colorado on the east and from Greeley on the north to Colorado Springs on the south. The four major bedrock aquifers from deepest to shallowest are the Laramie-Fox Hills Aquifer, the Arapahoe Aquifer, the Denver Aquifer, and the Dawson Aquifer. The Pierre Shale underlies these units and is considered the base of the Denver Basin bedrock aquifer system due to its great thickness (up to 8000 feet) and its low permeability (Robson and others, 1981a).

Presented below are discussions of the two Denver Basin bedrock aquifers which occur beneath Rocky Flats Plant - the Laramie-Fox Hills Aquifer and the

Arapahoe Aquifer. The Denver and Dawson Aquifers do not occur in the immediate vicinity of Rocky Flats Plant.

Laramie-Fox Hills Aquifer

The Laramie-Fox Hills Aquifer is composed of the upper sandstone and siltstone units of the Fox Hills Formation and the lower sandstone units of the Laramie Formation. The thickness of the aquifer ranges from zero near the aquifer boundaries to 200 to 300 feet near the center of the basin. The upper Laramie coals and claystones separate the Laramie-Fox Hills Aquifer from the overlying Arapahoe Aquifer (Robson and others, 1981b).

On a regional scale ground-water in the Laramie-Fox Hills Aquifer flows from outcrop recharge areas toward the center of the basin and discharges to remote stream valleys. In addition, ground water discharges to pumping wells in the basin (Robson and others, 1981b). In the vicinity of Rocky Flats Plant ground-water flow is generally from the west to the east.

Arapahoe Aquifer

The Arapahoe Aquifer is defined as the saturated portion of the Arapahoe Formation by Robson and others (1981a). The Arapahoe Formation consists of a 400 to 700 foot thick sequence of interbedded claystones, siltstones, sandstones, and conglomerates with claystones and shale being more prominent in the northern third of the basin (Robson and others, 1981a). Individual sandstone beds are commonly lens shaped and range from a few inches to 30 to 40 feet in thickness (Robson and others, 1981a). Beneath the Plant the majority of ground-water flow in the Arapahoe is in the lenticular sandstones contained within the claystones (Rockwell International, 1986a).

There are two primary methods of recharge to the Arapahoe Aquifer. In outcrop and subcrop areas, it occurs from infiltration of incident precipitation and as infiltration of water from shallow alluvial aquifers. However, on a regional scale the primary recharge mechanism for the Arapahoe Aquifer is leakage from the overlying Denver Aquifer (Robson and others, 1981a).

Ground-water flow in the Arapahoe Aquifer is from recharge areas at the edges of the basin toward discharge areas along incised stream valleys. Ground-water is also discharged to pumping wells (Robson and others, 1981a). Ground-water flow in the vicinity of Rocky Flats Plant is from west to east toward the area of regional discharge along the South Platte River.

3.4.3 Ground-Water Use

Usable ground water occurs in both the Laramie-Fox Hills and Arapahoe Aquifers. The Laramie-Fox Hills subcrops west of the Plant but has little potential for use in the general area because of its great depth (approximately 750 to 800 feet deeper than the Arapahoe). Various sandstones in the Arapahoe Aquifer are used for irrigation, livestock watering, and domestic purposes east of the Plant.

3.5 SURFACE WATER HYDROLOGY

3.5.1 Natural Drainages

Three ephemeral streams drain the Rocky Flats Plant with flow generally from west to east (Figure 3-8). Rock Creek drains the northwestern corner and flows to the northeast in the buffer zone to its off-site confluence with Coal Creek.

A topographic divide bisects the Plant. The divide trends east-west and lies slightly south of Central Avenue (the approximate center line of the Plant site). An interceptor ditch lies between the Plant and the southern drainage Woman Creek. The South Interceptor Ditch is tributary to the "C" Ponds. Surface runoff downstream of the interceptor ditch is tributary to Woman Creek, which flows eastward to Standley Lake. An irrigation ditch headgate located in the northeast quarter of the northwest quarter diverts water from Woman Creek and conveys it to a small reservoir known as Mower Reservoir. North and South Walnut Creeks and an unnamed tributary drain the remainder of the Plant. These three forks of Walnut Creek join in the buffer zone (approximately 0.7 miles downstream of the eastern edge of the Plant security area) and flow to Great Western Reservoir approximately one mile east of the confluence of the forks.

3.5.2 Ditches and Diversions

The Church and McKay ditches cross the northern portion of the Plant. Both carry water diverted from Coal Creek to Great Western Reservoir. A diversion structure has been built in North Walnut Creek upstream of the Plant to divert McKay ditch out of the drainage. The ditches parallel each other north of the

Present Landfill and enter the Walnut Creek drainage downstream of the confluence of the north and south forks.

In addition to the natural flows, there are six ditches in the general vicinity of the Plant. The Church, McKay, and Kinnear Ditch and Reservoir Co. Ditches (diversions of Coal Creek) cross the Plant. Church Ditch delivers water to Upper Church Lake and Great Western Reservoir (City of Broomfield municipal water storage). McKay Ditch also supplies water to Great Western Reservoir. Kinnear Ditch and Reservoir Co. Ditch diverts water from Coal Creek and delivers it to Standley Lake (municipal water storage for the City of Westminster) via Woman Creek. Woman Creek also delivers water to Mower Reservoir. Last Chance Ditch flows south of the Plant and delivers water to Rocky Flats Lake and Twin Lakes. Smart Ditch takes water from Rocky Flats Lake and transports it out of the area to the east. The South Boulder Diversion Canal runs along the western upgradient edge of the Plant diverting water from South Boulder Creek and delivering it to Ralston Reservoir (City of Denver municipal water storage).

3.5.3 Retention Ponds and Plant Discharges

A series of dams, retention ponds, diversion structures, and ditches has been constructed at the Plant to control surface water and limit the potential for release of poor quality water.

The ponds are located in the drainages of Walnut and Woman Creeks and are designated the A, B, and C series ponds. Discharges from the downstream pond in each series are in accordance with the Plant's National Pollution Discharge Elimination System (NPDES) permit. Ponds A-1 and A-2 are used only for spill control, and North Walnut Creek stream flow is diverted around them through an underground pipe. Pond A-3 receives the North Walnut Creek stream flow and Plant runoff from the northern portion of the Plant. Pond A-4 is designed for surface water control and for additional storage capacity for overflow from pond A-3.

Five retention ponds are located along South Walnut Creek and are designated as B-1, B-2, B-3, B-4, and B-5, from west to east. Ponds B-1 and B-2 are reserved for spill control, whereas pond B-3 receives treated effluent from the sanitary sewage treatment plant. Ponds B-4 and B-5 receive surface runoff and occasionally collect discharge from pond B-3. Pond B-5 receives runoff from the central portion of the Plant and is used for surface water control in addition to collection of overflow from pond B-4.

The two C series ponds, C-1 and C-2, are located along Woman Creek, south and east of the Plant, respectively. Pond C-1 receives stream flow from Woman Creek. This flow is diverted around pond C-2 into the Woman Creek channel downstream. Pond C-2 receives surface runoff from the South Interceptor Ditch along the southern portion of the Plant. Water in pond C-2 is discharged to Woman Creek in accordance with the Plant NPDES permit.

There are many runoff control ditches in the generally vicinity of the Plant. The largest of these is the Central Avenue Ditch which runs eastward along Central Avenue and discharges to South Walnut Creek (Pond B-5). The other major runoff control ditch is the South Interceptor Ditch which prevents runoff from the south side of the Plant from entering Woman Creek. The ditch discharges to pond C-2, and Woman Creek is diverted around pond C-2 by a diversion structure just upstream of the pond.

Another retention pond is located on the unnamed northern tributary of Walnut Creek, downstream of the Present Landfill (see Section 2.1). Following water quality analyses, the water from the landfill pond is spray irrigated onto an area south of the landfill but upstream of the pond.

The permit requires monitoring of specific parameters at seven discharge points. The permitted discharges are:

Discharge	Location
001	Pond B-3
002	Pond A-3
003	Reverse Osmosis Pilot Plant
004	Reverse Osmosis Plant
005	Pond A-4
006	Pond B-5
007	Pond C-2

The discharges from the ponds are regularly monitored to document compliance with NPDES permit requirements. In addition to NPDES monitoring requirements, all discharges are monitored for plutonium, americium, uranium, and tritium concentrations.

SECTION 4

SITE HYDROGEOLOGY

4.1 SITE GEOLOGY

Presented below are hydrogeologic and ground-water quality data collected during the Present Landfill investigations conducted in 1986 and 1987 as well as from previous investigations. The section begins with a detailed description of the surficial (4.1.1) and bedrock (4.1.2) geology including lithologies, thicknesses, and extent of materials found at the landfill. Ground-water hydrology and water quality data are discussed in Section 4.2.1 and 4.2.2 for surficial and bedrock flow systems, respectively.

Information for the discussion was obtained from previous studies, aerial photographs, 21 monitoring well borehole logs, and field mapping. Plate 2-1 shows the locations of all monitoring wells at the Rocky Flats Plant, and Plate 4-1 presents monitoring well locations at the Present Landfill. Geologic logs and well completion data sheets for the wells at the landfill are presented in Appendix B, and analytical data are presented in Appendixes C (recent data) and D (historical data).

4.1.1 Surficial Geology

Surficial materials in the landfill area consist of the Rocky Flats Alluvium, colluvium, valley fill alluvium, and artificial fill or disturbed ground which unconformably overlie the bedrock units. In addition, there are a few isolated exposures of claystone bedrock located along the side slopes of the drainage. Plate 4-2 presents the distribution of surficial materials based on interpretation of aerial photographs, field mapping, and borehole logs. The landfill is located on the western end of the unnamed tributary to North Walnut Creek. Rocky Flats Alluvium caps the top of the slopes on the north and south sides of the tributary while colluvium (slope wash) covers the hillsides down to the tributary. Artificial fill or disturbed surficial materials are present within the boundaries of the landfill; along major man-made drainage ways surrounding the landfill; and northwest of the landfill. Valley fill alluvium is present along the unnamed tributary channel.

4.1.1.1 Rocky Flats Alluvium

The Quaternary Rocky Flats Alluvium is the oldest and topographically highest alluvial deposit at the Rocky Flats Plant. It is Nebraskan in age (Scott, 1965) and is situated at an elevation of approximately 5,950 to 6,000 feet above mean sea level at the landfill area. The Rocky Flats Alluvium is a series of coalescing alluvial fans deposited by braided streams (Hurr, 1976). The erosional surface (pediment) on which the alluvium was deposited slopes gently eastward truncating the Arapahoe Formation at the landfill area.

After deposition of the Rocky Flats Alluvium, eastward flowing streams began dissecting the deposit by headward erosion and lateral planation. All of the alluvium was eroded from the unnamed tributary, and colluvium and valley fill alluvium were subsequently deposited along the slopes and in the unnamed tributary drainage, respectively.

The Rocky Flats Alluvium in the landfill area is described as a generally poorly sorted, unconsolidated deposit of clay, silt, sand, gravel, and cobbles. Colors of the alluvium range from light yellow (10 YR 5/4) (Geological Society of America

Rock-Color Chart, 1984] to dark brown (10 YR 4/2). In addition shades of various oranges, olives, grays, and pinks are interspersed throughout. Occasional reddish brown (10 YR 4/6) oxide staining is present. The grain size of the quartz and granitic sand encountered ranges from very fine to coarse-grained (3.0 Ø - 0.5 Ø on the Wentworth Scale). Quartzite and granitic gravels, pebbles, and cobbles, found throughout the area in thin (less than one inch) to moderately thick (greater than one foot) layers, are subangular to subrounded, indicative of materials transported short distances. They range in size from 0.25 mm to 4.75 mm with no one size being predominant. The Rocky Flats alluvium ranges between 6.5 (72-87) and 27.2 feet thick (60-87) with an average thickness of approximately 18.0 feet where undisturbed. Lenses of sand, gravel, and clay within the Rocky Flats Alluvium can be correlated between wells in close proximity to each other. Depositional features such as cut and fill sequences (Cross section E-E'), stratigraphic pinch-outs (Cross sections D-D' and E-E'), and lateral stratigraphic variations are evident in the cross sections (Plate 4-6).. These features are characteristic of braided stream deposits associated with alluvial fans and reflect the dynamic nature of the depositional environment.

4.1.1.2 Colluvium

Colluvial materials are present on the slopes descending to the unnamed tributary (Plate 4-2); however, only wells 7-86 and 8-86 penetrated colluvium in the vicinity of the landfill. Colluvium consists predominantly of clay with common occurrences of sandy clay and gravel layers. Colluvial clay is typically poorly consolidated and ranges from yellowish brown (10 YR 5/4) to dusky brown (5 YR 2/2) in color. The sandy intervals contain moderate yellowish brown (10 YR 5/4) to dark yellowish brown (10 YR 4/2) colors, and vary from very fine-grained to coarse-grained (4.0 Ø to 0.0 Ø), rounded to subangular quartzite sand.

4.1.1.3 Valley Fill Alluvium

The most recent deposit in the landfill area is the valley fill alluvium along the unnamed tributary channel. This alluvium is derived from reworked and redeposited older alluviums and bedrock material. Valley fill thickness ranges from 4 feet (5-86) to 8.0 feet (40-87) in the landfill area. The valley fill materials generally become finer-grained downstream of the landfill. Alluvial deposits in well 42-87 are described as predominantly gravel with abundant cobbles and pebbles, whereas well 5-86, further downgradient of the landfill in the unnamed tributary, encountered predominantly very fine-grained sand and gravels with occasional cobbles.

The unconsolidated valley fill consists of poorly sorted sand, gravel, and pebbles in a silty clay matrix. Colors range from brown (5 YR 5/6) to grayish orange pink (5 YR 7/2) with areas of gray brown (5 YR 3/2) to yellow brown (10 YR 5/4). Quartzite, granite, and schistose gravels are generally angular to subangular and unsorted.

4.1.1.4 Disturbed Ground

There are two types of disturbed ground at the landfill. The first is derived from excavations of Church Ditch located northwest of the landfill and ground associated with the building of the dam across the tributary. The core of the east pond embankment was constructed of compacted clay and claystones with the outer shell being composed of clayey sands, gravels, and cobbles. These materials were taken from borrow areas. The disturbed ground in the Church Ditch area likely consists of reworked Rocky Flats Alluvium.

The second type of disturbed ground consists of the material comprising the landfill itself. It is described as a mixture of clay, gravel, coarse sand, asphalt fragments, wire, plastics, surgical gloves, wood particles, and other materials associated with landfilling activities. Cross-sections A-A',B-B', C-C', D-D', and E-E' (Plates 4-4, 4-5, and 4-6) show landfill areas as disturbed ground underlain by Rocky Flats alluvium (wells 61-87, 62-87, 63-87, 64-87, and 65-87). Thicknesses of the fill material where drilled ranged from approximately 1.5 feet to approximately 27 feet in the center of the landfill (Woodward-Clevenger, 1974). Fill thicknesses are greater in the center of the landfill according to the test holes drilled by Woodward-Clevenger in 1974. Cross-sections D-D' and E-E' show the landfill leachate collection/ground-water diversion system which has been included in the surficial geology map as disturbed ground.

4.1.2 Bedrock Geology

The Cretaceous Arapahoe Formation underlies surficial materials at the Present Landfill. Six wells were completed in various zones of the bedrock during the 1986 and 1987 drilling programs. The Arapahoe Formation beneath the landfill consists of claystone and interbedded sandstones and siltstones with a thin isolated shale layer encountered in well 8-86. The Arapahoe Formation was deposited by meandering streams flowing generally west to east off the Front Range. Sandstones were deposited as braided stream channel deposits and overbank splays. Claystones were deposited in back swamp and floodplain areas. Leaf fossils, black organic matter, and wood fragments were encountered within the claystones during drilling at the landfill. Contacts between various lithologies are both gradational and sharp.

4.1.2.1 Arapahoe Formation Claystones

Claystone was the most frequently encountered lithology of the Arapahoe Formation immediately below the Quaternary/Cretaceous contact (Cross-sections A-A' through E-E'; Plates 4-4, 4-5, and 4-6). Claystones are described as massive and blocky containing occasional thin laminae and interbeds of sands and silt.

Weathered bedrock was encountered directly beneath surficial materials in all of the monitoring wells and test holes drilled during previous investigations. Weathering penetrates approximately 2 feet (well 6-86) to 11 feet (well 9-86) into bedrock. The weathered claystones generally range from pale yellowish brown (10 YR 6/2) to light olive gray (5 YR 5/6), and are moderately oxide stained, blocky and layered. Stains may also occur as brown and red mottling. Iron oxide concretions along with sporadic caliche and abundant black organic fragments were noted in the zone. A few fractures were noted in the core from well 41-87 at depths of 9.5-12 feet.

Unweathered claystone is typically dark gray (N 3/0) to yellowish gray (5 Y 7/2) and has little mottling. Vertical to subvertical fracturing in claystone was noted in the core from well 9-86 between 42 and 60.5 feet, and again from 79.0 to 84.0 feet below ground surface. These fractures were lined with dark yellowish orange (10 YR 6/6) to dusky purple (5 P 2/2) limonite staining.

Both weathered and unweathered claystone contains horizons of very fine silt and sand. Typical silt and sand horizons range in color from brownish gray (5 YR 4/1) to dark yellowish orange (10 YR 6/6).

4.1.2.2 Arapahoe Formation Sandstones

Bedrock wells 8-86, 9-86, and 41-87BR are completed in Arapahoe Formation sandstones. In addition wells 58-87, 64-87, 65-87, 70-87, and 72-87 encountered shallow or subcropping bedrock sandstones. These sandstones are generally composed of moderately to well sorted, subrounded to rounded, very fine- to medium-grained quartz sand. Cementation increases with depth as weathering decreases. Sandstone bed thicknesses ranged from approximately 2.5 feet in well 8-86 to 20 feet in well 41-87. The sandstone in wells 41-87 and 9-86 are homogeneous and contain thin beds and laminae of fine silt and clay. Crossbedding was also noted in 9-86. The sandstone color ranged from light gray (N 7/0) in well 65-87 to olive black (5 Y 2/1) in well 41-87, which contained some organics (fossilized) at approximately 68.0 feet and again between 86.0 and 90.0 feet.

Weathered sandstone is lithologically similar to unweathered sandstone. In well 64-87 it was dark yellowish orange (10 YR 6/6) to light brown (5 YR 5/6) from approximately 24.5 feet to 28 feet below ground surface and weakly cemented.

Siltstones were encountered in the Arapahoe Formation associated with the sandstones as gradational units of silty sandstone or sandy siltstone. Well 9-86 encountered relatively homogeneous layers of unweathered siltstone at 89.0 to 122.0 feet and again at 139.0 to 144.0 feet. They are described as dark gray (N 3/0) to greenish gray (5 G 6/1), clayey, trace very fine-grained sand, very carbonaceous, and slightly calcareous with woody fragments and convoluted bedding.

Subcropping sandstones were encountered during drilling at well locations 65-87, 72-87, and 70-87 (Cross sections F-F' and C-C'). Subcropping is defined as consolidated sandstone directly underlying the unconsolidated surficial material. Subcropping sandstones were not fully penetrated during the drilling of 70-87 and 72-87; therefore, the thickness of the unit cannot be determined at this time. The sandstones are described as weathered, weakly cemented, varying in color from light gray (N 7/0) to moderate brown (5 YR 4/4) with pale yellowish browns (10 YR 6/2). Sand was generally fine-grained (3.5-2.5 Ø), subrounded to rounded, poorly to moderately sorted, moderately iron oxide stained, massive and blocky.

Cross-section C-C' depicts the subcropping sandstones in wells 70-87 and 72-87 as interconnected based on their lithologic descriptions and physical proximity to one another. Plate 4-3 shows the estimated areal extent beneath the alluvium of subcropping sandstones associated with these two wells based on a 3.5 foot thick unit and a seven degree easterly dip and the relatively flat topography capping the slope. This is only an estimate since neither borehole (70-87 or 72-87) fully penetrated the sandstone unit. The seven degree dip is based on the correlation of the sandstone unit encountered in wells 9-87 and 16-87 in the 903 Pad Area. These sandstone units were correlated on the basis of similar lithologies and therefore a seven degree dip was established (Rockwell International, 1987b).

A second, smaller subcropping sandstone area is associated with wells 64-87 and 65-87. Approximately 3.2 feet of subcropping sandstone was encountered at well 65-87 while well location 64-87 contains a weathered clayey sandstone at a depth of approximately one foot below the Quaternary/Cretaceous contact. These sandstones are similar with the exception of color; 64-87 is dark yellowish orange (10 YR 6/6) to light brown (5 YR 5/6) while 65-87 varies from light gray (N 6/0) to moderate brown (5 YR 4/4).

A few correlations between sandstones of the Arapahoe Formation can be made when an easterly dip of seven degrees is applied. Three sandstone units were encountered during the drilling of well 41-87BR (A-A'). The upper sandstone (32.5 to 53.0 feet below ground surface) appears to subcrop underneath the present landfill pond. The second sandstone unit (64.7 to 73.5 feet below ground surface) pinches out up dip. The lowest sandstone unit (79.6 to 101.0 feet below ground surface) connects with the uppermost sandstone encountered in well 8-85 and probably pinches out dip because the bed appears to be thinning up dip. In addition, the lowermost sandstone encountered in 8-86 (59.5 to 63.6 feet below ground surface) correlates with the subcropping sandstone found during the drilling of 65-87.

4.2 GROUND-WATER HYDROLOGY

Ground water occurs in surficial materials (Rocky Flats Alluvium, colluvium, valley fill alluvium, and disturbed ground) and in Arapahoe sandstones and claystones at the Present Landfill. These two hydraulically connected flow systems are discussed separately below.

4.2.1 Ground-water System in Surficial Materials

Ground water is present in surficial materials at the Present Landfill under unconfined conditions.

4.2.1.1 Recharge/Discharge Conditions

Recharge to the water table occurs as infiltration of incident precipitation and from localized spraying of water from the landfill pond. In addition, intermittent recharge occurs as infiltration from ditches and creeks and possibly as seepage from the landfill pond along the eastern embankment.

Discharge from the water table occurs as evapotranspiration and as seepage into the landfill pond, creeks, and springs. In addition, ground water is discharged from the surficial ground-water system into the underlying bedrock ground-water system.

The surficial ground-water flow system is quite dynamic, with large water level changes occurring in response to precipitation events and to stream and ditch flow. Hurr (1976) describes the rapid response of water levels in wells completed in Rocky Flats Alluvium to surface flows in irrigation ditches.

There are also seasonal variations in the saturated thickness of the surficial materials. Hydrographs showing saturated thickness over time are found for most wells in Appendix B. In general, water-level data for wells completed in Rocky Flats Alluvium, valley fill, and disturbed ground are available from September 1986 for the 1986 wells. Data are available as early as August 1987 for 1987 wells, although for most of these wells recorded data begins in January 1988. In view of the limited amount of data available for many wells, full analysis of seasonal variations in saturated thickness is not possible at this time.

There are three wells completed downgradient of the Present Landfill (wells 7-86, 40-87 in valley fill alluvium, and 42-87 in colluvium). Well 7-86 is adjacent to the landfill pond, and wells 40-87 and 42-87 are downstream of the pond. Saturated thickness in each of these wells has never been in excess of 5 feet, and all of the wells were dry part of the year.

Most of the wells completed in Rocky Flats Alluvium at the Present Landfill were installed in the fall of 1987. Therefore only limited water level data are available for these wells. Water level data are available for over a full year for the two 1986 wells completed in Rocky Flats Alluvium at the landfill (10-86 and 45-86). Both of these wells are upgradient of the landfill.

The hydrograph of well 10-86 indicates that the saturated thickness varies sinusoidally. The maximum saturated thickness occurs during April and May, and the minimum occurs in December. The hydrograph of well 45-86 is in rough agreement, although the minimum occurs in October.

4.2.1.2 Ground-water Flow

Natural ground-water flow in the vicinity of the Present Landfill is eastward through the Rocky Flats Alluvium following topography toward ephemeral streams (Plate 4-7 and 4-8). In the vicinity of the landfill the ground-water intercept system is designed to divert the natural ground-water flow around the landfill; however, this diversion does not appear to be working effectively at all locations. Other diversions may also occur due to the presence of slurry trenches, although this cannot be conclusively stated at this time. Within the landfill, ground-water flow generally follows topography from west to east toward the landfill pond.

<u>Leachate/Ground-water Collection System</u>

-- <u>Design</u>

In order to control ground-water flow around the landfill, a two-part leachate and ground-water collection system was constructed in 1974. This system was designed to collect and divert ground-water around the outside of the landfill and to collect leachate generated in the landfill.

As shown on Plate 4-1, the two-part system is approximately 24 feet in width at its base. The design drawings show the leachate collection trench (shown on Plate 4-1 as "landfill trench") approximately 12 feet in width at the bottom with side slopes of 2:1. A five-foot thick gravel blanket was placed in the bottom of the system to facilitate grater flow of leachate collected in the system. The collection system was constructed by excavating a trench around the perimeter of the solid wastes to depths of 10 to 25 feet. The ground-water collection portion of the system is located on the exterior of the excavation and is separated from the leachate collection portion of the system by a 4.5-foot wide zone of clayey soil (clayey silt/sandy clay). The clayey soil zone was designed to be extended 2 feet into bedrock in order to prevent ground-water flows into the landfill. An 8-inch perforated pipe is located on the outside of the wall immediately above the bedrock contact. Ground water flows into the pipe drain and is diverted around the landfill. A series of valves determine the discharge area for the flow. Review of the aerial photographs shows the location of the installed interceptor ditch. In addition, the Present Landfill pond (Pond No. 2) and leachate pond (Pond No. 1) are seen for the first time on aerial photographs from 1975.

Field reconnaissance, a review of the borehole logs, topographic maps, and previous reports has shown that the landfill wastes bury the leachate collection system and extend beyond the system (Rockwell International, 1986a). Therefore, leachate generated outside the landfill trench would be collected by the ground-water collection system. In addition, the clay cutoff wall no longer extends to the surface of the landfill; therefore, water could enter the landfill if high enough.

No conclusive evidence has been uncovered to verify that the clay surface seal (liner) extends into bedrock as specified in the construction diagrams. The lithologic logs for the 1986 and 1987 boreholes encountered bedrock at approximately 25 feet below ground surface. Design cross sections indicate that the cutoff wall and trench invert do not always penetrate bedrock. Appendix 1 of the Landfill Closure Plan contain profiles of the landfill trench. As shown in Drawing Number 27317-2 in Appendix 1, the trench may not extend into bedrock in one area on the southwest side of the landfill.

-- <u>Conclusions</u>

The following conclusions regarding the effectiveness of the leachate/ground-water intercept system have been made based on water level and ground-water quality data:

1) The ground-water intercept system is diverting ground-water away from the west end of the landfill along cross section E-E';

2) the ground-water intercept is not diverting ground-water away from the north and south sides of the landfill along cross section D-D';

3) The clay barrier is holding degraded ground water in the landfill along the west and north sides;

4) The clay barrier is ineffective on the south side of the landfill and is allowing contaminated ground water to leave the landfill;

5) The leachate collection system appears to function intermittently on the north side of the landfill.

The efficiency of the ground-water intercept system at the west end of the landfill is displayed in Cross section E-E' (Plate 4-6). Three wells (10-86, 58-87, and 59-87) are screened in the Rocky Flats Alluvium west of the ground-water intercept.

The water level in well 59-87 (immediately adjacent to the intercept) is lower that those in wells 10-86 and 58-87 indicating the ground-water intercept is accepting ground water at this location. No conclusion can be drawn as to the effectiveness of the leachate collection system at this location as there is no well east of 59-87 and the intercept system.

In contrast, the water table profiles in Cross section D-D' (Plate 4-6) indicate ground-water is not effectively draining into the system at the north and south ends of the cross section. There is no appreciable difference in water levels across the ground-water intercept system.

A comparison of water levels through time along the northern end of cross section D-D' suggests the clay liner and leachate collection system work intermittently. Figure 4-1 presents water levels for wells along Cross section E-E' plotted by date. Water levels in well 63-87 (inside the landfill) track those in wells 60-87, 61-87, and 62-87 (outside the landfill and intercept system) for three of the four months of available data. However, in January 1988, well 63-87 is dry, while water levels outside the landfill remain relatively constant. This indicates the clay liner is acting as a hydraulic barrier, and the leachate collection system is draining intermittently. In addition, water levels in well 62-87 (outside the interceptor system) have remained below the top of the clay liner estimated at an elevation of 5,980 feet. This further supports the contention that the barrier is effectively separating ground water inside the landfill from ground water outside the landfill.

It should be noted that the above conclusions are drawn on a total of four water levels per well. Because the only significant discrepancy occurs in the first month of sampling,

Figure 4-1

Elevation of Water Table for Wells 60-87 through 63-87

(Landfill)

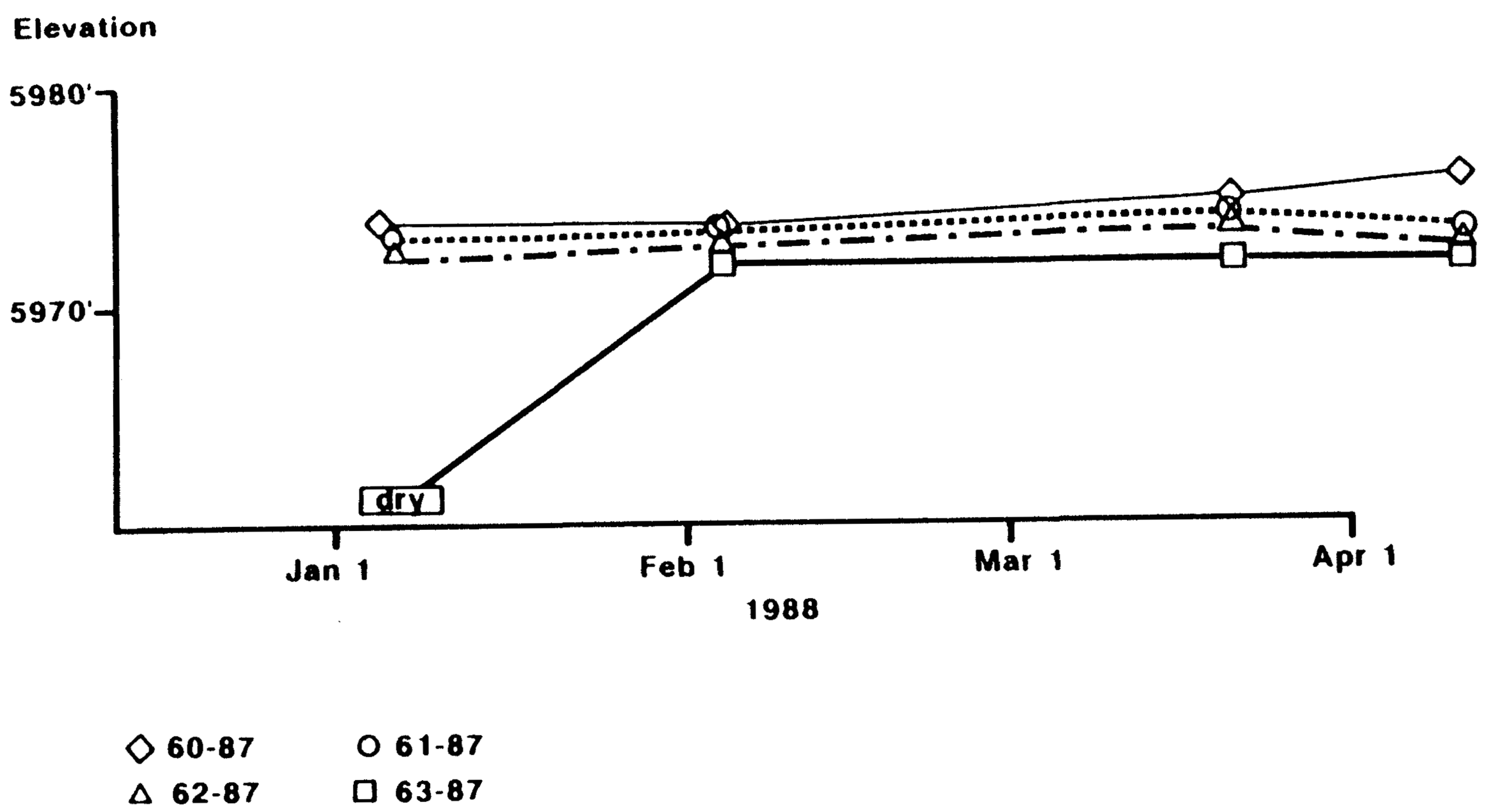
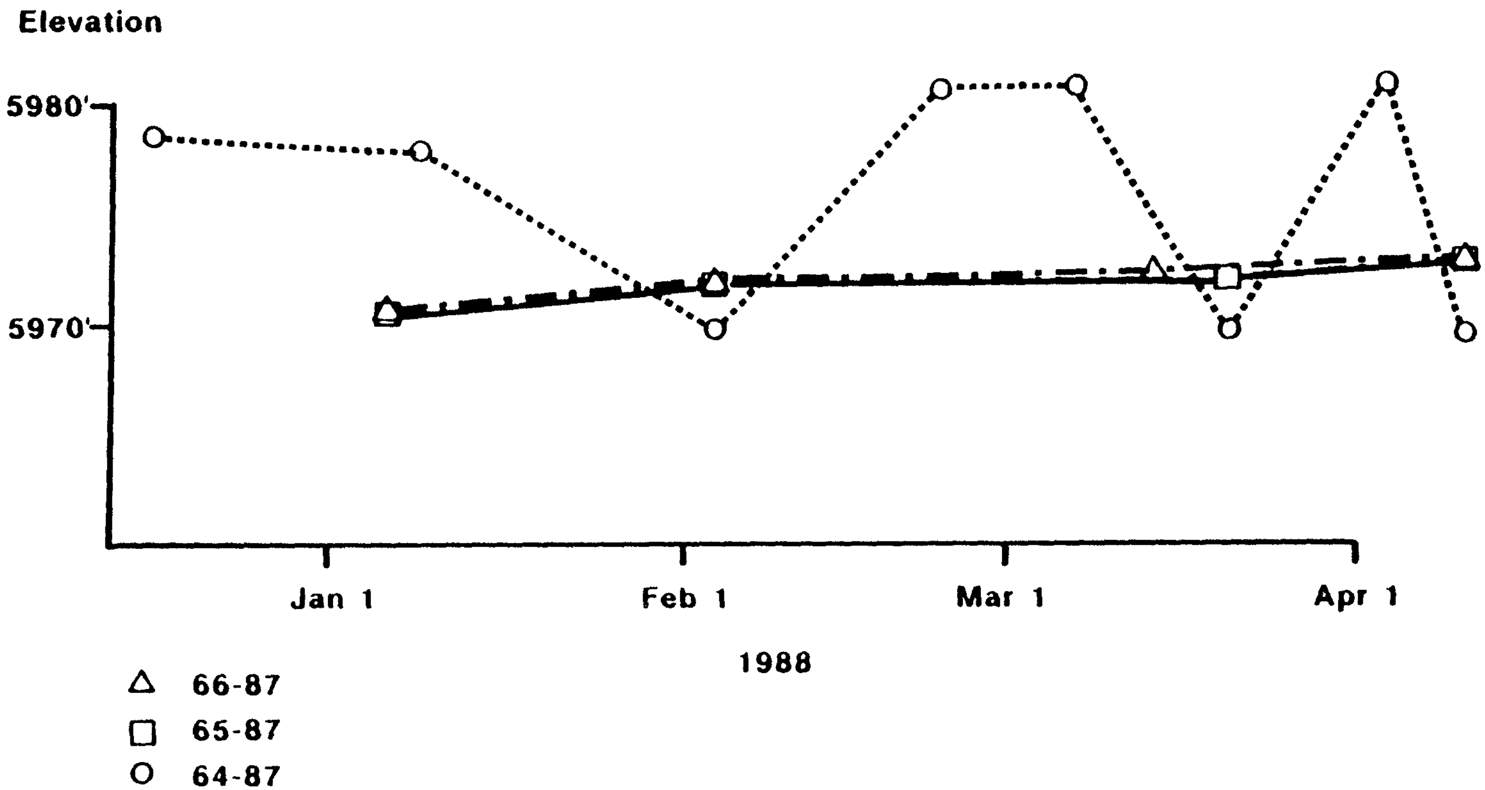


Figure 4-2

Elevation of Water Table for Wells 64-87 through 66-87

(Landfill)



the possibility exists that this is due to an initially poor well development in 63-87; however, this is not documented.

Based on water levels in wells along the southern end of Cross section D-D', the clay liner and leachate collection system at this location are not functioning properly. Figure 4-2 presents water levels through time along this cross section. Water levels in well 64-87 (inside the landfill) fluctuated up to ten feet over the four month period, while water levels in wells 65-87 and 66-87 (outside the landfill) remained constant. In fact, water levels in well 64-87 exceeded those in wells 65-87 and 66-87 during January, March, and April, 1988, when water levels in 64-87 reached elevations of 5979.83, 5980.43, and 5980.63, creating the potential for ground-water flow out of the landfill toward the south. As shown in Cross section D-D', well 65-87 intersected the top of the clay liner. This clay liner is associated with the clay encountered 2.5 feet below ground surface in this well. This places the elevation of the clay liner at this location at 5980.58 feet. This suggests that water elevations at well 64-87 will not exceed approximately 5981 feet in elevation because at this elevation water within the landfill will overspill the clay liner and discharge to the south across the clay liner. Ground-water quality data, as discussed in Section 4.2.1.6, support the conclusion that alluvial ground-water has spilled over the clay liner and exited the landfill at this location.

Slurry Trenches

A slurry trench is a curtain of low permeability material initially emplaced in trenches as a slurry. The purpose is to impede the flow of ground water. A description of the slurry trenches installed north and south of the landfill pond (Plate

4-1) is provided in Section 2.2 of the Landfill Closure Plan. Design drawings for the slurry trenches are presented in Appendix 1 of this closure plan.

The location of the north and south slurry trenches are shown in Plate 4-1. The well pair 67-87 and 68-87 straddle the north slurry trench. In Table 4-1, water-surface elevations for well pair 67-87 and 68-87 are listed. Except for January 1988, the difference between water elevations is slight. Determination of the degree of hydraulic continuity existing across the north slurry trench will require a pump test at some future date.

As shown in Plate 4-1, wells do not straddle the south slurry trench. Consequently, no evaluation of the south slurry trench can be made. Well 70-87 located upgrade and south of the south slurry trench is dry January through March 1988, but has a saturated thickness of 6.82 feet in April. Ground-water flow in this locale is limited for part of the year by unsaturated conditions.

It should be noted that a subcropping sandstone was found in wells 72-87 and 70-87. A comparison of this sandstone subcrop in Plate 4-3 and the location of the south slurry trench in Plate 4-1 indicates that approximately 40 percent of the southern slurry trench is underlain by subcropping sandstone. This suggests that it is likely that some degree of hydraulic continuity may extend across the eastern end of the southern slurry trench when saturated alluvium is present.

4.2.1.3 Hydraulic Conductivity of Surficial Materials

Hydraulic conductivity values were developed for surficial materials from drawdown-recovery tests performed on 1986 wells during the initial site

TABLE 4-1

ROCKY FLATS PRESENT LANDFILL
WATER LEVEL SUMMARY

	67-87	68-87
DATE	WATER SURFACE ELEVATION	SURFACE ELEVATION
01/06/88	5967.42	5960.51
02/04/88	5961.32	5961.21
03/21/88	5961.72	5961.51
04/11/88	5961.82	5962.11

characterization (Rockwell International, 1986a) and from slug tests performed on select 1987 wells during this remedial investigation. Drawdown-recovery tests were analyzed using the Residual Drawdown Plot (Driscoll, 1986) and the method of Bouwer (1978), and slug tests were analyzed by the method of Bouwer and Rice (1976). Results of these tests are summarized in Table 4-2. Test data and analyses are presented in Appendix B.

Hydraulic conductivity values for the Rocky Flats Alluvium range from 1.3×10^{-3} centimeters per second (cm/s) [1300 feet per year (ft/yr)] at well 60-87 to 1.6×10^{-5} cm/s (1.6 ft/yr) at well 58-87 with a geometric mean of 2.4×10^{-4} cm/s (240 ft/yr).

4.2.1.4 BASIS FOR GROUND-WATER QUALITY ASSESSMENT

This evaluation of chemical conditions is based on all data collected since 1986 when detailed ground-water investigations began at the Plant. Some of the 1986 wells have six quarters of analytical results, i.e., the last quarter of 1986 (initial site characterization results), four quarters of 1987, and the first quarter of 1988. Wells completed in 1987 have first quarter, 1988 analytical data only. Table 4-3 lists the analyses performed on ground-water samples, and Table 4-4 summarizes the availability of alluvial ground-water quality data used in this report. Analytical data are presented in Appendix C and summary tables for alluvial wells sample results are presented in Table 4-5.

TABLE 4-2

RESULTS OF HYDRAULIC CONDUCTIVITY TESTS OF SURFICIAL MATERIALS

Well No.	Formation	Lithology Screened	DRAWDOWN RECOVERY Test (cm/s)	SLUG TESTS (cm/s)
45-86	Q_{RF}	SAND AND POORLY SORTED GRAVEL	2.1×10^{-5}	
58-87	Q_{RF}	SAND, POORLY SORTED GRAVEL, AND CLAYEY SAND	1.6×10^{-5}	
60-87	Q_{RF}	SAND AND GRAVEL GRADING TO CLAYEY SAND AND CLAY		1.3×10^{-3}
61-87	Q_{RF}	SAND		9.9×10^{-4}
62-87	Q_{RF}	SAND AND GRAVEL, CLAYEY SAND,AND CLAY		6.2×10^{-4}
63-87	Q_{RF}	SAND AND GRAVEL, SANDY CLAY		6.7×10^{-4}
65-87	Q_{RF}/KA_{SS}	CLAYEY SAND, SANDSTONE		4.6×10^{-4}
66-87	Q_{RF}	SAND AND SANDY CLAY		1.8×10^{-4}
67-87	Q_{RF}	CLAYEY SAND		6.4×10^{-5}
71-87	Q_{RF}	CLAYEY SAND GRADING TO SANDY CLAY		6.6×10^{-4}

Q_{RF} = ROCKY FLATS ALLUVIUM
KA_{SS} = ARAPAHOE SANDSTONE

TABLE 4-3

GROUND-WATER AND SURFACE WATER SAMPLING PARAMETERS

FIELD PARAMETERS
pH
Specific Conductance
Temperature
Dissolved Oxygen*

INDICATORS
Total Dissolved Solids
Total Suspended Solids*

METALS**
Hazardous Substances List - Metals
- Aluminum
- Antimony
- Arsenic
- Barium
- Beryllium
- Cadmium
- Calcium
- Cesium
- Chromium (total)
- Cobalt
- Copper
- Iron
- Lead
- Magnesium
- Manganese
- Mercury
- Molybdenum
- Nickel
- Potassium
- Selenium
- Silver
- Sodium
- Thallium
- Tin
- Vanadium
- Zinc

~~Chromium (hexavalent)~~
Lithium
Strontium

TABLE 4-3

GROUND-WATER AND SURFACE WATER SAMPLING PARAMETERS (CONTINUED)

ANIONS
Carbonate
Bicarbonate
Chloride
Sulfate
Nitrate

ORGANICS
Hazardous Substances List - Volatiles***
Oil and Grease

RADIONUCLIDES
Gross Alpha
Gross Beta
Uranium 233, 234, 235, and 238
Americium 241
Plutonium 239
Strontium 90
Cesium 137
Tritium

* For surface water samples only.

** Dissolved metals for ground-water samples, total and dissolved metals for surface water samples.

*** Ground-water samples from the first, second, and third quarters of 1987, and all surface water samples were analyzed by the Rockwell 881 Laboratory for only 9 of the HSL volatiles. These volatiles are the chlorinated solvents historically detected in the ground water and are as follows: PCE, TCE, 1,1-DCE, 1,2-DCA, t-1,2-DCE, 1,1,1-TCA, 1,1,2-TCA, CCl_4, and $CHCl_3$. Ground-water samples from fourth quarter 1987 and first quarter 1988 were analyzed for HSL volatiles with the exception of 2-chloroethylvinyl ether.

Table 4-4

GROUND WATER SAMPLE INFORMATION

LANDFILL ALLUVIAL WELLS

WELL	SAMPLE INFORMATION			FIELD PARAMETERS			LABORATORY BATCH NUMBERS					
NUMBER	NUMBER	DATE	TYPE	pH	CONDUCT (umho/cm)	TEMP (deg C)	VOLATILE ORGANICS	SEMI-VOL ORGANICS	PESTICIDES AND PCB'S	METALS	INORGANICS	RADIO-CHEMISTRY
0586	DRY	09/08/86										
0586	5-86-05-05-87	05/05/87	Routine	7.10	3500	1.0	0187-881-073	No Sample	No Sample	0187-881-073	0187-881-075	0187-881-075
0586	5-86-06-09-87	06/09/87	Routine	7.20	6260	12.6	0287-881-038	No Sample	No Sample	0287-881-038	0287-881-041	0287-881-038
0586	5-86-07-31-87	07/31/87	Routine	7.20	7480	16.5	Insufficient Sample	No Sample	No Sample	0387-881-069	0387-881-068	0387-881-046
0686	DRY	09/08/86										
0686	6-86-05-13-87	05/13/87	Routine	6.90	6630	11.9	0187-881-097	No Sample	No Sample	0187-881-097	0187-881-096	0187-881-118
0686	6-86-06-09-87	06/09/87	Routine	7.20	4380	11.3	0287-881-082	No Sample	No Sample	Insufficient Sample	Insufficient Sample	Insufficient Sample
0686	6-86-08-10-87	08/10/87	Routine	7.00	5660	16.0	0387-881-074	No Sample	No Sample	Insufficient Sample	Insufficient Sample	Insufficient Sample
0686	08-86-02-01-88	02/01/88	Routine				0188-881-020	No Sample	No Sample	Insufficient Sample	Insufficient Sample	Insufficient Sample
0786	DRY	09/29/86										
0786	DRY	08/10/87										
0786	07-86-02-01-88	02/01/88	Routine				0188-881-021	No Sample	No Sample	Insufficient Sample	Insufficient Sample	Insufficient Sample
1086	G1086108600	10/16/86	Routine	6.60	205	15.5	8610-044-031	No Sample	No Sample	8610-044-032	8610-044-033	Insufficient Sample
1086	10-86-05-14-87	05/14/87	Routine	5.90	203	12.0	0187-881-100	No Sample	No Sample	0187-881-100	0187-881-103	0187-881-105
1086	10-86-06-15-87	06/15/87	Routine	7.50	164	13.9	0287-881-047	No Sample	No Sample	0287-881-047	0287-881-050	0287-881-047
1086	10-86-08-10-87	08/10/87	Routine	6.90	211	16.0	0387-881-076	No Sample	No Sample	0387-881-083	0387-881-081	0387-881-059
1086	10-86-12-15-87	12/15/87	Routine	5.80	154	11.0	0487-881-067	No Sample	No Sample	0487-881-061	0487-881-053	0487-881-056
1086	10-86-02-02-88	02/02/88	Routine	8.20	206	9.2	0188-881-015	No Sample	No Sample	0188-881-015	0188-881-015	0188-881-015
4087	DRY	08/10/87										
4087	DRY	02/01/88										
4287	GW4287	06/24/87	Routine				8706-079-0010	No Sample	No Sample	Insufficient Sample	Insufficient Sample	Insufficient Sample
4287	DRY	08/10/87										
4287	42-87-12-16-87	12/16/87	Routine				0487-881-072	No Sample	No Sample	Insufficient Sample	Insufficient Sample	Insufficient Sample
4287	42-87-02-04-88	02/04/88	Routine	7.00	701	5.0	0188-881-017	No Sample	No Sample	0188-881-017	0188-881-017	0188-881-017
4586	G4586108600	10/16/86	Routine	6.70	240	12.0	8610-044-006	8610-055-002	8610-055-002	8610-044-007	8610-044-008	1000-000-287
4586	G4586108662	10/16/86	Field Duplicate	6.70	220	12.0	8610-044-016	8610-055-004	8610-055-004	8610-044-017	8610-044-018	1000-000-289
4586	45-86-05-15-87	05/14/87	Routine	6.40	91	12.0	0187-881-098	No Sample	No Sample	0187-881-098	0187-881-106	0187-881-108
4586	45-86-06-12-87	06/12/87	Routine	6.50	114	14.7	0287-881-043	No Sample	No Sample	0287-881-043	0287-881-046	0287-881-043
4586	45-86-08-14-87	08/14/87	Routine	5.80	87	12.1	0387-881-084	No Sample	No Sample	0387-881-089	0387-881-087	0387-881-065
4586	45-86-09-30-87	09/30/87	Field Split				8710-006-0050	No Sample	No Sample	No Sample	No Sample	No Sample
4586	45-86-09-30-87	09/30/87	Routine	6.90	105	15.3	0487-881-001	No Sample	No Sample	0487-881-005	0487-881-001	0487-881-020
4586	45-86-10-01-87	10/01/87	Field Split				No Sample	No Sample	No Sample	No Sample	No Sample	0187-123-013
5887	58-87-01-23-88	01/23/88	Routine	8.10	342	10.0	0188-881-001	No Sample	No Sample	0188-881-001	0188-881-001	0188-881-001
5987	59-87-01-23-88	01/23/88	Routine	7.20	656	12.2	0188-881-002	No Sample	No Sample	0188-881-002	0188-881-002	0188-881-002

Table 4-4 (cont'd.)

GROUND WATER SAMPLE INFORMATION

LANDFILL ALLUVIAL WELLS

	SAMPLE INFORMATION			FIELD PARAMETERS			LABORATORY BATCH NUMBERS					
WELL NUMBER	NUMBER	DATE	TYPE	pH	CONDUCT (umho/cm)	TEMP (deg C)	VOLATILE ORGANICS	SEMI-VOL ORGANICS	PESTICIDES AND PCB'S	METALS	INORGANICS	RADIO-CHEMISTRY
6087	60-87-01-23-88	01/23/88	Routine	7.10	215	10.9	0188-881-003	No Sample	No Sample	0188-881-003	0188-881-003	0188-881-003
6187	61-87-01-27-88	01/27/88	Routine	7.50	170	13.3	0188-881-006	No Sample	No Sample	0188-881-006	0188-881-006	0188-881-006
6287	62-87-01-26-88	01/26/88	Routine	7.30	227	12.3	0188-881-004	No Sample	No Sample	0188-881-004	0188-881-004	0188-881-004
6387	63-87-01-27-88	01/27/88	Routine	7.00	624	13.4	0188-881-005	No Sample	No Sample	0188-881-005	0188-881-005	0188-881-005
6487	64-87-01-29-88	01/29/88	Routine	7.00	463	11.4	Insufficient Sample	No Sample	No Sample	0188-881-014	0188-881-014	0188-881-014
6587	65-87-01-28-88	01/28/88	Routine	7.20	685	13.3	0188-881-010	No Sample	No Sample	0188-881-010	0188-881-010	0188-881-010
6687	66-87-01-29-88	01/29/88	Routine	7.30	689	9.8	Insufficient Sample	No Sample	No Sample	0188-881-012	0188-881-012	0188-881-012
6787	67-87-01-28-88	01/28/88	Routine	7.00	390	10.8	0188-881-008	No Sample	No Sample	0188-881-008	0188-881-008	0188-881-008
6887	68-87-01-28-88	01/28/88	Routine	7.00	390	10.4	0188-881-009	No Sample	No Sample	0188-881-009	0188-881-009	0188-881-009
7087	DRY	02/03/88										
7187	71-87-01-29-88	01/29/88	Routine	7.50	564	7.8	Insufficient Sample	No Sample	No Sample	0188-881-013	0188-881-013	0188-881-013
7287	72-87-01-28-88	01/28/88	Routine	7.20	685	7.9	0188-881-011	No Sample	No Sample	0188-881-011	0188-881-011	0188-881-011

Table

Groundwater Volatile ...nic Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Chloro methane	Bromo methane	Vinyl Chloride	Chloro ethane	Methylene Chloride	Acetone	Carbon Disulfide	1,1-Dichloro ethene	1,1-Dichloro ethane	Trans-1,2 Dichloro ethene
Landfill Alluvial Wells Upgradient														
1086	G108610860	10/16/86		ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
1086	10-86-05-14-87	05/14/87	1	ug/l	NR	NR	NR	NR	NR	NR	NR	4 U	NR	4 U
1086	10-86-06-15-87	06/15/87	2	ug/l	NR	NR	NR	NR	NR	NR	NR	4 U	NR	4 U
1086	10-86-08-10-87	08/10/87	3	ug/l	NR	NR	NR	NR	NR	NR	NR	5 U	NR	5 U
1086	10-86-12-15-87	12/15/87	4	ug/l	10 U	10 U	10 U	10 U	9	10 U	5 U	5 U	5 U	5 U
1086	10-86-02-02-88	02/02/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
4586	G458610860	10/16/86		ug/l	10 U	10 U	10 U	10 U	5 U	15 B	5 U	5 U	5 U	5 U
4586	G458610862	10/16/86		ug/l	10 U	10 U	10 U	10 U	5 U	3 BJ	5 U	5 U	5 U	5 U
4586	45-86-05-15-87	05/14/87	1	ug/l	NR	NR	NR	NR	NR	NR	NR	4 U	NR	4 U
4586	45-86-06-12-87	06/12/87	2	ug/l	NR	NR	NR	NR	NR	NR	NR	4 U	NR	4 U
4586	45-86-08-14-87	08/14/87	3	ug/l	NR	NR	NR	NR	NR	NR	NR	5 U	NR	5 U
4586	45-86-09-30-87	09/30/87		ug/l	10 U	10 U	10 U	10 U	5 U	1 JB	5 U	5 U	5 U	5 U
4586	45-86-09-30-87	09/30/87	4	ug/l	NR	NR	NR	NR	NR	NR	NR	5 U	NR	5 U
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	13	5 U	5 U	5 U	5 U

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-5 (

Groundwater Volatile .ic Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr	Units	Chloroform	1,2 Dichloro ethane	2 Butanone	1,1,1-Trichloro ethane	Carbon Tetra chloride	Vinyl Acetate	Bromo dichloro methane	1,2 Dichloro propane	Trans-1,3-Dichloro propene	Trichloro ethene
Landfill Alluvial Wells Upgradient														
1086	G1086108600	10/16/86		ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
1086	10-86-05-14-87	05/14/87	1	ug/l	4 U	4 U	NR	4 U	4 U	NR	NR	NR	NR	4 U
1086	10-86-06-15-87	06/15/87	2	ug/l	4 U	4 U	NR	4 U	4 U	NR	NR	NR	NR	4 U
1086	10-86-08-10-87	08/10/87	3	ug/l	5 U	5 U	NR	5 U	5 U	NR	NR	NR	NR	5 U
1086	10-86-12-15-87	12/15/87	4	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
1086	10-86-02-02-88	02/02/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
4586	G4586108600	10/16/86		ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
4586	G4586108602	10/16/86		ug/l	5 U	5 U	6 J	5 U	5 U	10 U	5 U	5 U	5 U	5 U
4586	45-86-05-15-87	05/14/87	1	ug/l	4 U	4 U	NR	4 U	4 U	NR	NR	NR	NR	4 U
4586	45-86-06-12-87	06/12/87	2	ug/l	4 U	4 U	NR	4 U	4 U	NR	NR	NR	NR	4 U
4586	45-86-08-14-87	08/14/87	3	ug/l	5 U	5 U	NR	5 U	5 U	NR	NR	NR	NR	5 U
4586	45-86-09-30-87	09/30/87		ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
4586	45-86-09-30-87	09/30/87	4	ug/l	5 U	5 U	NR	5 U	5 U	NR	NR	NR	NR	5 U
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1	ug/l	5 U	5 U	10 U	5 U	8	10 U	5 U	5 U	5 U	5 U

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4- ...'d.)

Groundwater Volatile O...anic Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Dibromo chloro methane	1,1,2-Trichloro ethane	Benzene	cis-1,3 Dichloro propene	2-Chloro ethylvinyl ether	Bromoform	4-Methyl-2-pentanone	2-Hexanone	Tetrachloro ethene	1,1,2,2-Tetrachloro ethane
Landfill Alluvial Wells Upgradient														
1086	G1086108б0	10/16/86		ug/l	5 U	5 U	5 U	5 U	10 U	5 U	10 U	10 U	5 U	5 U
1086	10-86-05-14-87	05/14/87	1	ug/l	NR	4 U	NR	NR	NR	NR	NR	NR	4 U	NR
1086	10-86-06-15-87	06/15/87	2	ug/l	NR	4 U	NR	NR	NR	NR	NR	NR	4 U	NR
1086	10-86-08-10-87	08/10/87	3	ug/l	NR	5 U	NR	NR	NR	NR	NR	NR	5 U	NR
1086	10-86-12-15-87	12/15/87	4	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
1086	10-86-02-02-88	02/02/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
4586	G458610860	10/16/86		ug/l	5 U	5 U	5 U	5 U	10 U	5 U	10 U	10 U	5 U	5 U
4586	G458610862	10/16/86		ug/l	5 U	5 U	5 U	5 U	10 U	5 U	10 U	10 U	5 U	5 U
4586	45-86-05-15-87	05/14/87	1	ug/l	NR	4 U	NR	NR	NR	NR	NR	NR	4 U	NR
4586	45-86-06-12-87	06/12/87	2	ug/l	NR	4 U	NR	NR	NR	NR	NR	NR	4 U	NR
4586	45-86-08-14-87	08/14/87	3	ug/l	NR	5 U	NR	NR	NR	NR	NR	NR	5 U	NR
4586	45-86-09-30-87	09/30/87		ug/l	5 U	5 U	5 U	5 U	10 U	5 U	10 U	10 U	5 U	5 U
4586	45-86-09-30-87	09/30/87	4	ug/l	NR	5 U	NR	NR	NR	NR	NR	NR	5 U	NR
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-5

Groundwater Volatile O[illegible]anic Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Toluene	Chloro benzene	Ethyl benzene	Styrene	Total Xylenes
Landfill Alluvial Wells Upgradient									
1086	G108610860	10/16/86		ug/l	5 U	5 U	5 U	5 U	5 U
1086	10-86-05-14-87	05/14/87	1	ug/l	NR	NR	NR	NR	NR
1086	10-86-06-15-87	06/15/87	2	ug/l	NR	NR	NR	NR	NR
1086	10-86-08-10-87	08/10/87	3	ug/l	NR	NR	NR	NR	NR
1086	10-86-12-15-87	12/15/87	4	ug/l	5 U	5 U	5 U	5 U	5 U
1086	10-86-02-02-88	02/02/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
4586	G458610860	10/16/86		ug/l	5 U	5 U	5 U	1 J	5 U
4586	G458610862	10/16/86		ug/l	5 U	5 U	5 U	2 J	5 U
4586	45-86-05-15-87	05/14/87	1	ug/l	NR	NR	NR	NR	NR
4586	45-86-06-12-87	06/12/87	2	ug/l	NR	NR	NR	NR	NR
4586	45-86-08-14-87	08/14/87	3	ug/l	NR	NR	NR	NR	NR
4586	45-86-09-30-87	09/30/87		ug/l	5 U	5 U	5 U	5 U	5 U
4586	45-86-09-30-87	09/30/87	4	ug/l	NR	NR	NR	NR	NR
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1	ug/l	5 U	5 U	5 U	5 U	5 U

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table [illegible]t'd.)

Groundwater Volatile [illegible]ic Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Chloro methane	Bromo methane	Vinyl Chloride	Chloro ethane	Methylene Chloride	Acetone	Carbon Disulfide	1,1-Dichloro ethene	1,1-Dichloro ethane	Trans 1,2-Dichloro ethene
Landfill Alluvial Wells Downgradient														
0586	DRY	09/08/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0586	5-86-05-05-87	05/05/87	1	ug/l	NR	NR	NR	NR	NR	NR	NR	4 U	NR	4 U
0586	5-86-06-09-87	06/09/87	2	ug/l	NR	NR	NR	NR	NR	NR	NR	4 U	NR	4 U
0586	5-86-07-31-87	07/31/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0786	DRY	09/29/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0786	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0786	07-86-02-01-88	02/01/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
4087	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4087	DRY	02/01/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4287	GW4287	06/24/87	2	ug/l	10 U	10 U	10 U	10 U	5 U	26 B	5 U	5 U	5 U	5 U
4287	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4287	42-87-12-16-87	12/16/87	4	ug/l	10 U	10 U	10 U	10 U	12	10 U	5 U	5 U	5 U	5 U
4287	42-87-02-04-88	02/04/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
5987	59-87-01-23-88	01/23/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
6087	60-87-01-23-88	01/23/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
6187	61-87-01-27-88	01/27/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
6287	62-87-01-26-88	01/26/88	1	ug/l	10 U	10 U	10 U	10 U	6	10 U	5 U	5 U	5 U	5 U
0686	DRY	09/08/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0686	6-86-05-13-87	05/13/87	1	ug/l	NR	NR	NR	NR	NR	NR	NR	4 U	NR	4 U
0686	6-86-06-09-87	06/09/87	2	ug/l	NR	NR	NR	NR	NR	NR	NR	4 U	NR	4 U
0686	6-86-08-10-87	08/10/87	3	ug/l	NR	NR	NR	NR	NR	NR	NR	5 U	NR	5 U
0686	08-86-02-01-88	02/01/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
6387	63-87-01-27-88	01/27/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
6487	64-87-01-29-88	01/29/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6587	65-87-01-28-88	01/28/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
6687	66-87-01-29-88	01/29/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6787	67-87-01-28-88	01/28/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
6887	68-87-01-28-88	01/28/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
7087	DRY	02/03/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7187	71-87-01-29-88	01/29/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7287	72-87-01-28-88	01/28/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
0486	DRY	08/28/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0486	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
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Table 4 d.)

Groundwater Volatile nic Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Chloroform	1,2-Dichloro ethane	2-Butanone	1,1,1 Trichloro ethane	Carbon Tetra chloride	Vinyl Acetate	Bromo dichloro methane	1,2-Dichloro propane	Trans 1,3 Dichloro propene	Trichloro ethene
Landfill Alluvial Wells Downgradient														
0586	DRY	09/08/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0586	5-86-05-05-87	05/05/87	1	ug/l	4 U	4 U	NR	4 U	4 U	NR	NR	NR	NR	4 U
0586	5-86-06-09-87	06/09/87	2	ug/l	4 U	4 U	NR	4 U	4 U	NR	NR	NR	NR	4 U
0586	5-86-07-31-87	07/31/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0786	DRY	09/29/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0786	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0786	07-86-02-01-88	02/01/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
4087	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4087	DRY	02/01/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4287	GW4287	06/24/87	2	ug/l	5 U	5 U	2.0 J	5 U	5 U	10 U	5 U	5 U	5 U	5 U
4287	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4287	42-87-12-16-87	12/16/87	4	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
4287	42-87-02-04-88	02/04/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
5987	59-87-01-23-88	01/23/88	1	ug/l	5 U	5 U	10 U	5 U	6	10 U	5 U	5 U	5 U	5 U
6087	60-87-01-23-88	01/23/88	1	ug/l	5 U	5 U	10 U	5 U	7	10 U	5 U	5 U	5 U	5 U
6187	61-87-01-27-88	01/27/88	1	ug/l	5 U	5 U	10 U	5 U	8	10 U	5 U	5 U	5 U	5 U
6287	62-87-01-26-88	01/26/88	1	ug/l	5 U	5 U	10 U	5 U		10 U	5 U	5 U	5 U	5 U
0686	DRY	09/08/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0686	6-86-05-13-87	05/13/87	1	ug/l	4 U	4 U	NR	4 U	4 U	NR	NR	NR	NR	4 U
0686	6-86-06-09-87	06/09/87	2	ug/l	4 U	4 U	NR	4 U	4 U	NR	NR	NR	NR	4 U
0686	6-86-08-10-87	08/10/87	3	ug/l	5 U	5 U	NR	5 U	5 U	NR	NR	NR	NR	5 U
0686	08-86-02-01-88	02/01/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
6387	63-87-01-27-88	01/27/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
6487	64-87-01-29-88	01/29/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6587	65-87-01-28-88	01/28/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
6687	66-87-01-29-88	01/29/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6787	67-87-01-28-88	01/28/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
6887	68-87-01-28-88	01/28/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
7087	DRY	02/03/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7187	71-87-01-29-88	01/29/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7287	72-87-01-28-88	01/28/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	17
0486	DRY	08/28/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0486	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-[illegible] [illegible].)

Groundwater Volatile [illegible]anic Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr	Units	Dibromo chloro methane	1,1,2 Trichloro ethane	Benzene	cis-1,3-Dichloro propene	2 Chloro ethylvinyl ether	Bromoform	4-Methyl-2-pentanone	2-Hexanone	Tetrachloro ethene	1,1,2,2-Tetrachloro ethane
Landfill Alluvial Wells Downgradient														
0586	DRY	09/08/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0586	5-86-05-05-87	05/05/87	1	ug/l	NR	4 U	NR	NR	NR	NR	NR	NR	4 U	NR
0586	5-86-06-09-87	06/09/87	2	ug/l	NR	4 U	NR	NR	NR	NR	NR	NR	4 U	NR
0586	5-86-07-31-87	07/31/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0786	DRY	09/29/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0786	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0786	07-86-02-01-88	02/01/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
4087	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4087	DRY	02/01/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4287	GW4287	06/24/87	2	ug/l	5 U	5 U	5 U	5 U	10 U	5 U	10 U	10 U	5 U	5 U
4287	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4287	42-87-12-16-87	12/16/87	4	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
4287	42-87-02-04-88	02/04/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
5987	59-87-01-23-88	01/23/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
6087	60-87-01-23-88	01/23/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
6187	61-87-01-27-88	01/27/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
6287	62-87-01-26-88	01/26/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
0686	DRY	09/08/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0686	6-86-05-13-87	05/13/87	1	ug/l	NR	4 U	NR	NR	NR	NR	NR	NR	4 U	NR
0686	6-86-06-09-87	06/09/87	2	ug/l	NR	4 U	NR	NR	NR	NR	NR	NR	4 U	NR
0686	6-86-08-10-87	08/10/87	3	ug/l	NR	5 U	NR	NR	NR	NR	NR	NR	5 U	NR
0686	08-86-02-01-88	02/01/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
6387	63-87-01-27-88	01/27/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
6487	64-87-01-29-88	01/29/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6587	65-87-01-28-88	01/28/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
6687	66-87-01-29-88	01/29/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6787	67-87-01-28-88	01/28/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
6887	68-87-01-28-88	01/28/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
7087	DRY	02/03/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7187	71-87-01-29-88	01/29/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7287	72-87-01-28-88	01/28/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
0486	DRY	08/28/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0486	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-5 /

Groundwater Volatile .nic Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Toluene	Chloro benzene	Ethyl benzene	Styrene	Total Xylenes
Landfill Alluvial Wells Downgradient									
0586	DRY	09/08/86			NA	NA	NA	NA	NA
0586	5-86-05-05-87	05/05/87	1	ug/l	NR	NR	NR	NR	NR
0586	5-86-06-09-87	06/09/87	2	ug/l	NR	NR	NR	NR	NR
0586	5-86-07-31-37	07/31/87	3		NA	NA	NA	NA	NA
0786	DRY	09/29/86			NA	NA	NA	NA	NA
0786	DRY	08/10/87	3		NA	NA	NA	NA	NA
0786	07-86-02-01-88	02/01/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
4087	DRY	08/10/87	3		NA	NA	NA	NA	NA
4087	DRY	02/01/88	1		NA	NA	NA	NA	NA
4287	GW4287	06/24/87	2	ug/l	5 U	5 U	5 U	5 U	5 U
4287	DRY	08/10/87	3		NA	NA	NA	NA	NA
4287	42-87-12-16-87	12/16/87	4	ug/l	5 U	5 U	5 U	5 U	5 U
4287	42-87-02-04-88	02/04/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
5987	59-87-01-23-88	01/23/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
6087	60-87-01-23-88	01/23/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
6187	61-87-01-27-88	01/27/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
6287	62-87-01-26-88	01/26/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
0686	DRY	09/08/86			NA	NA	NA	NA	NA
0686	6-86-05-13-87	05/13/87	1	ug/l	NR	NR	NR	NR	NR
0686	6-86-06-09-87	06/09/87	2	ug/l	NR	NR	NR	NR	NR
0686	6-86-08-10-87	08/10/87	3	ug/l	NR	NR	NR	NR	NR
0686	08-86-02-01-88	02/01/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
6387	63-87-01-27-88	01/27/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
6487	64-87-01-29-88	01/29/88	1		NA	NA	NA	NA	NA
6587	65-87-01-28-88	01/28/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
6687	66-87-01-29-88	01/29/88	1		NA	NA	NA	NA	NA
6787	67-87-01-28-88	01/28/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
6887	68-87-01-28-88	01/28/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
7087	DRY	02/03/88	1		NA	NA	NA	NA	NA
7187	71-87-01-29-88	01/29/88	1		NA	NA	NA	NA	NA
7287	72-87-01-28-88	01/28/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
0486	DRY	08/28/86			NA	NA	NA	NA	NA
0486	DRY	08/10/87	3		NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4- d.)

Groundwater Semivolati rganic Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Phenol	bis(2-Chloro ethyl)Ether	2-Chloro phenol	1,3-Dichloro benzene	1,4-Dichloro benzene	Benzyl Alcohol	1,2-Dichloro benzene	2-Methyl phenol	bis(2-Chloro isopropyl) Ether	4-Methyl phenol
Landfill Alluvial Wells Upgradient														
1086	G108610860	10/16/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-05-14-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-06-15-87	06/15/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-08-10-87	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-12-15-87	12/15/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-02-02-88	02/02/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	G458610860	10/16/86		ug/l	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
4586	G458610862	10/16/86		ug/l	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
4586	45-86-05-15-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-06-12-87	06/12/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-08-14-87	08/14/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-5 (Continued)

Groundwater Semivolatile Organic Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	N Nitroso-di-n-propylamine	Hexachloro ethane	Nitro benzene	Isophorone	2 Nitro phenol	2,4 Dimethyl phenol	Benzoic Acid	bis(2-Chloro ethoxy) Methane	2,4-Dichloro phenol	1,2,4-Trichloro benzene
Landfill Alluvial Wells Upgradient														
1086	G108610860	10/16/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-05-14-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-06-15-87	06/15/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-08-10-87	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-12-15-87	12/15/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-02-02-88	02/02/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	G458610860	10/16/86		ug/l	10 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U
4586	G458610862	10/16/86		ug/l	10 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U
4586	45-86-05-15-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-06-12-87	06/12/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-08-14-87	08/14/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4- d.)

Groundwater Semivolati. ganic Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Napthalene	4-Chloro aniline	Hexachloror butadiene	4-chloro-3-methyl phenol	2 Methyl naphthalene	Hexachloro cyclo pentadiene	2,4,6-Trichloro phenol	2,4,5-Trichloro phenol	2-Chloro naphthalene	2-Nitro aniline
Landfill Alluvial Wells Upgradient														
1086	G1086i0860	10/16/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-05-14-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-06-15-87	06/15/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-08-10-87	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-12-15-87	12/15/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-02-02-88	02/02/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	G4586i0860	10/16/86		ug/l	10 U	10 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	50 U
4586	G4586i0862	10/16/86		ug/l	10 U	10 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	50 U
4586	45-86-05-15-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-06-12-87	06/12/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-08-14-87	08/14/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-5 .)

Groundwater Semivolatil ganic Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Dimethyl Phthalate	Ace naphthylene	3-Nitro aniline	Ace naphthene	2,4-Dinitro phenol	4-Nitro phenol	Dibenzo furan	2,4-Dinitro toluene	2,6-Dinitro toluene	Diethyl phthalate
Landfill Alluvial Wells Upgradient														
1086	G108610860	10/16/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-05-14-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-06-15-87	06/15/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-08-10-87	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-12-15-87	12/15/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-02-02-88	02/02/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	G458610860	10/16/86		ug/l	10 U	10 U	50 U	10 U	50 U	50 U	10 U	10 U	10 U	10 U
4586	G458610862	10/16/86		ug/l	10 U	10 U	50 U	10 U	50 U	50 U	10 U	10 U	10 U	10 U
4586	45-86-05-15-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-06-12-87	06/12/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-08-14-87	08/14/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-5 ( )

Groundwater Semivolati ... nic Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	4-Chloro phenyl-phenylether	Fluorene	4-Nitro aniline	4,6-Dinitro-2-methyl phenol	N-Nitrosodi phenylamine	4-Bromophenyl-phenylether	Hexachloro benzene	Pentachloro phenol	Phenanthrene	Anthracene
Landfill Alluvial Wells Upgradient														
1086	G1086108б0	10/16/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-05-14-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-06-15-87	06/15/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-08-10-87	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-12-15-87	12/15/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-02-02-88	02/02/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	G4586108б0	10/16/86		ug/l	10 U	10 U	50 U	50 U	10 U	10 U	10 U	50 U	10 U	10 U
4586	G4586108б2	10/16/86		ug/l	10 U	10 U	50 U	50 U	10 U	10 U	10 U	50 U	10 U	10 U
4586	45-86-05-15-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-06-12-87	06/12/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-08-14-87	08/14/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table [illegible]t'd.)

Groundwater Semivolatile [illegible]ganic Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	di-n-Butyl Phthalate	Fluoranthene	Pyrene	Butyl Benzyl Phthalate	3,3'-Dichloro benzidine	Benzo(a) Anthracene	bis(2-Ethylhexyl) Phthalate	Chrysene	di-n-Octyl Phthalate	Benzo(b) Fluoranthene
Landfill Alluvial Wells Upgradient														
1086	G108610860	10/16/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-05-14-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-06-15-87	06/15/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-08-10-87	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-12-15-87	12/15/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-02-02-88	02/02/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	G458610860	10/16/86		ug/l	4 JB	10 U	10 U	1 J	20 U	10 U	7 JB	10 U	10 U	10 U
4586	G458610862	10/16/86		ug/l	4 JB	10 U	10 U	10 U	20 U	10 U	4 JB	10 U	10 U	10 U
4586	45-86-05-15-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-06-12-87	06/12/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-08-14-87	08/14/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-5

Groundwater Semivolatile ganic Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Benzo(k) Fluoranthene	Benzo(a) Pyrene	Indeno (1,2,3-cd) Pyrene	Dibenz(a,h) Anthracene	Benzo(g,h,i) Perylene
Landfill Alluvial Wells Upgradient									
1086	G108610860	10/16/86			NA	NA	NA	NA	NA
1086	10-86-05-14-87	05/14/87	1		NA	NA	NA	NA	NA
1086	10-86-06-15-87	06/15/87	2		NA	NA	NA	NA	NA
1086	10-86-08-10-87	08/10/87	3		NA	NA	NA	NA	NA
1086	10-86-12-15-87	12/15/87	4		NA	NA	NA	NA	NA
1086	10-86-02-02-88	02/02/88	1		NA	NA	NA	NA	NA
4586	G458610860	10/16/86		ug/l	10 U	10 U	10 U	10 U	10 U
4586	G458610862	10/16/86		ug/l	10 U	10 U	10 U	10 U	10 U
4586	45-86-05-15-87	05/14/87	1		NA	NA	NA	NA	NA
4586	45-86-06-12-87	06/12/87	2		NA	NA	NA	NA	NA
4586	45-86-08-14-87	08/14/87	3		NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4		NA	NA	NA	NA	NA
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1		NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4 .'d.)

Groundwater Ra..ochemistry Results

for Regulated Units at Rocky Flats Plant

Well Number	Field Sample Number	Date Sampled	Qtr.	Gross Alpha	Gross Beta	Uranium 233, 234	Uranium 235	Uranium 238	Strontium 89, 90	Plutonium 239, 240
Landfill Alluvial Wells Upgradient										
1086	G108610860	10/16/86		NA	NA	NA	NA	NA	NA	NA
1086	10-86-05-14-87	05/14/87	1	35 +/- 31 pc/l	68 +/- 5 pc/l	1.1 +/- 1.5 pc/l	.01 +/- .40 pc/l	4.3 +/- 1.9 pc/l	9.3 pc/l	.13 +/- .74 pc/l
1086	10-86-06-15-87	06/15/87	2	249 +/- 15 pci/l	171 +/- 35 pci/l	0.22 +/- 0.61 pci/l	0.0 +/- 0.29 pci/l	0.05 +/- 0.38 pci/l	1.6 pci/l	0.0 +/ 0.64 pci/l
1086	10-86-08-10-87	08/10/87	3	69 +/- 33 pci/l	62 +/- 45 pci/l	0.4 +/- 1.3 pci/l	2.6 +/- 0.9 pci/l	4.5 +/- 1.5 pci/l	2.7 pci/l	.32 +/- .61 pci/l
1086	10-86-12-15-87	12/15/87	4	29 +/- 8 pci/l	35 +/- 13 pci/l	.11 +/- .09 pci/l	0.00 +/- .02 pci/l	.02 +/- .07 pci/l	<1.0 pci/l	0.00 +/- .15 pci/l
1086	10-86-02-02-88	02/02/88	1	2 +/- 4 pci/l	-9 +/- 11 pci/l	6.3 +/- 0.6 pci/l	0.24 +/- 0.09 pci/l	5.1 +/- 0.5 pci/l	NR	0.00 +/- 0.32 pci/l
4586	G458610860	10/16/86		200 +/- 80 pci/l	140 +/- 30 pci/l	11 +/- 1 pci/l	NR	10 +/- 1 pci/l	NR	0.13 +/- 0.21 pci/l
4586	G458610862	10/16/86		190 +/- 100 pci/l	250 +/- 40 pci/l	15 +/- 2 pci/l	NR	16 +/- 2 pci/l	NR	-0.02 +/- 0.08 pci/l
4586	45-86-05-15-87	05/14/87	1	55 +/- 21 pc/l	23 +/- 15 pc/l	1.5 +/- 1.1 pc/l	.28 +/- .49 pc/l	1.0 +/- 0.9 pc/l	1.61 pc/l	4.7 +/- 1.8 pc/l
4586	45-86-06-12-87	06/12/87	2	0 +/- 0 pci/l	18 +/- 21 pci/l	0.0 +/- 0.59 pci/l	0.0 +/- 0.36 pci/l	0.0 +/- 0.35 pci/l	1.0 pci/l	0.0 +/- 0.68 pci/l
4586	45-86-08-14-87	08/14/87	3	25 +/- 24 pci/l	27 +/- 41 pci/l	2.0 +/- 1.5 pci/l	0.2 +/- 0.6 pci/l	9.8 +/- 2.3 pci/l	2.1 pci/l	.10 +/- .86 pci/l
4586	45-86-09-30-87	09/30/87		NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4	21 +/- 5 pci/l	26 +/- 10 pci/l	0.00 +/- 0.06 pci/l	0.00 +/- 0.03 pci/l	0.02 +/- 0.96 pci/l	<1.0 pci/l	0.00 +/- 0.09 pci/l
4586	45-86-10-01-87	10/01/87	4	NR	NR	0.099 +/- 0.174 pci/l	NR	0.085 +/- 0.053 pci/l	NR	0.106 +/- 0.062 pci/l
5887	58-87-01-23-88	01/23/88	1	9 +/- 6 pci/l	3 +/- 12 pci/l	0.49 +/- 0.23 pci/l	0.07 +/- 0.07 pci/l	0.48 +/- 0.20 pci/l	NR	0.00 +/- 0.27 pci/l

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis

Table .t'd.)

Groundwater R .hemistry Results

for Regulated Units at Rocky Flats Plant

Well Number	Field Sample Number	Date Sampled	Qtr	Americium 241	Cesium 137	Tritium
Landfill Alluvial Wells Upgradient						
1086	G108610860	10/16/86		NA	NA	NA
1086	10-86-05-14-87	05/14/87	1	0.0 +/- 1.5 pc/l	NR	<110 pc/l
1086	10-86-06-15-87	06/15/87	2	0.0 +/- 1.3 pci/l	NR	<110 pci/l
1086	10-86-08-10-87	08/10/87	3	0.0 +/- 1.4 pci/l	NR	<540 pci/l
1086	10-86-12-15-87	12/15/87	4	0.00 +/- .10 pci/l	NR	<220 pci/l
1086	10-86-02-02-88	02/02/88	1	NR	NR	<210 pci/l
4586	G458610860	10/16/86		0.03 +/- 0.07 pci/l	NR	0.10 +/- 0.22 pci/ml
4586	G4586108б2	10/16/86		-0.01 +/- 0.03 pci/l	NR	0.13 +/- 0.22 pci/ml
4586	45-86-05-15-87	05/14/87	1	0.0 +/- 1.4 pc/l	NR	<110 pc/l
4586	45-86-06-12-87	06/12/87	2	0.0 +/- 1.5 pci/l	NR	330 pci/l
4586	45-86-08-14-87	08/14/87	3	.69 +/- .91 pci/l	NR	<535 pci/l
4586	45-86-09-30-87	09/30/87		NA	NA	NA
4586	45-86-09-30-87	09/30/87	4	0.00 +/- 0.44 pci/l	NR	460 pci/l
4586	45-86-10-01-87	10/01/87	4	-0.019 +/- 0.036 pci/l	NR	NR
5887	58-87-01-23-88	01/23/88	1	0.00 +/- 0.44 pci/l	NR	210 pci/l

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis

Table .nt'd.)

Groundwater R. :hemistry Results

for Regulated Units at Rocky Flats Plant

Well Number	Field Sample Number	Date Sampled	Qtr.	Gross Alpha	Gross Beta	Uranium 233, 234	Uranium 235	Uranium 238	Strontium 89, 90	Plutonium 239, 240
Landfill Alluvial Wells Downgradient										
0586	DRY	09/08/86		NA	NA	NA	NA	NA	NA	NA
0586	5-86-05-05-87	05/05/87	1	126 +/- 102 pc/l	79 +/- 2. pc/l	79 +/- .09 pc/l	1.6 +/- 0.9 pc/l	.49 +/- .06 pc/l	<0.6 pc/l	0.7 +/- 1.1 pci/l
0586	5-86-06-09-87	06/09/87	2	NR	NR	NR	NR	NR	NR	0.0 +/- 0.6 pci/l
0586	5-86-07-31-87	07/31/87	3	NR	NR	NR	NR	NR	NR	-.32 +/- .97
0786	DRY	09/29/86		NA	NA	NA	NA	NA	NA	NA
0786	DRY	08/10/87	3	NA	NA	NA	NA	NA	NA	NA
0786	07-86-02-01-88	02/01/88	1	NA	NA	NA	NA	NA	NA	NA
4087	DRY	08/10/87	3	NA	NA	NA	NA	NA	NA	NA
4087	DRY	02/01/88	1	NA	NA	NA	NA	NA	NA	NA
4287	GW4287	06/24/87	2	NA	NA	NA	NA	NA	NA	NA
4287	DRY	08/10/87	3	NA	NA	NA	NA	NA	NA	NA
4287	42-87-12-16-87	12/16/87	4	NA	NA	NA	NA	NA	NA	NA
4287	42-87-02-04-88	02/04/88	1	8 +/- 5 pci/l	5 +/- 13 pci/l	0.08 +/- 0.11 pci/l	0.02 +/- 0.07 pci/l	0.00 +/- 0.09 pci/l	NR	0.02 +/- 0.24 pci/l
5987	59-87-01-23-88	01/23/88	1	14 +/- 7 pci/l	5 +/- 12 pci/l	5.3 +/- 0.6 pci/l	0.22 +/- 0.10 pci/l	4.4 +/- 0.6 pci/l	NR	0.00 +/- 0.24 pci/l
6087	60-87-01-23-88	01/23/88	1	10 +/- 8 pci/l	-9 +/- 12 pci/l	0.60 +/- 0.11 pci/l	0.00 +/- 0.05 pci/l	0.01 +/- 0.09 pci/l	NR	0.00 +/- 0.27 pci/l
6187	61-87-01-27-88	01/27/88	1	0 +/- 7 pci/l	-4 +/- 11 pci/l	0.00 +/- 0.07 pci/l	0.01 +/- 0.05 pci/l	0.08 +/- 0.08 pci/l	NR	0.00 +/- 0.24 pci/l
6287	62-87-01-26-88	01/26/88	1	8 +/- 6 pci/l	1 +/- 12 pci/l	0.01 +/- 0.10 pci/l	0.02 +/- 0.05 pci/l	0.01 +/- 0.08 pci/l	NR	0.01 +/- 0.19 pci/l
0686	DRY	09/08/86		NA	NA	NA	NA	NA	NA	NA
0686	6-86-05-13-87	05/13/87	1	NR	NR	NR	NR	NR	NR	0.0 +/- 0.8 pci/l
0686	6-86-06-09-87	06/09/87	2	NA	NA	NA	NA	NA	NA	NA
0686	6-86-08-10-87	08/10/87	3	NA	NA	NA	NA	NA	NA	NA
0686	08-86-02-01-88	02/01/88	1	NA	NA	NA	NA	NA	NA	NA
6387	63-87-01-27-88	01/27/88	1	17 +/- 7 pci/l	8 +/- 15 pci/l	4.6 +/- 0.4 pci/l	0.18 +/- 0.07 pci/l	3.6 +/- 0.3 pci/l	NR	0.21 +/- 0.22 pci/l
6487	64-87-01-29-88	01/29/88	1	2 +/- 4 pci/l	16 +/- 11 pci/l	0.62 +/- 0.37 pci/l	0.02 +/- 0.11 pci/l	0.84 +/- 0.44 pci/l	NR	0.00 +/- 0.40 pci/l
6587	65-87-01-28-88	01/28/88	1	10 +/- 6 pci/l	8 +/- 11 pci/l	5.4 +/- 1.9 pci/l	0.27 +/- 0.39 pci/l	4.3 +/- 1.6 pci/l	NR	0.01 +/- 0.14 pci/l
6687	66-87-01-29-88	01/29/88	1	2 +/- 4 pci/l	15 +/- 11 pci/l	0.80 +/- 0.16 pci/l	0.01 +/- 0.04 pci/l	0.50 +/- 0.13 pci/l	NR	0.01 +/- 0.18 pci/l
6787	67-87-01-28-88	01/28/88	1	19 +/- 7 pci/l	3 +/- 13 pci/l	0.57 +/- 0.18 pci/l	0.00 +/- 0.05 pci/l	0.48 +/- 0.13 pci/l	NR	0.02 +/- 0.14 pci/l
6887	68-87-01-28-88	01/28/88	1	1 +/- 4 pci/l	-1 +/- 12 pci/l	0.05 +/- 0.10 pci/l	0.00 +/- 0.04 pci/l	0.16 +/- 0.10 pci/l	NR	0.00 +/- 0.16 pci/l
7087	DRY	02/03/88	1	NA	NA	NA	NA	NA	NA	NA
7187	71-87-01-29-88	01/29/88	1	5 +/- 5 pci/l	17 +/- 10 pci/l	0.22 +/- 0.13 pci/l	0.07 +/- 0.08 pci/l	0.08 +/- 0.10 pci/l	NR	0.00 +/- 0.15 pci/l
7287	72-87-01-28-88	01/28/88	1	6 +/- 5 pci/l	-3 +/- 13 pci/l	5.8 +/- 0.9 pci/l	0.27 +/- 0.15 pci/l	4.2 +/- 0.7 pci/l	NR	0.00 +/- 0.19 pci/l
0486	DRY	08/28/86		NA	NA	NA	NA	NA	NA	NA
0486	DRY	08/10/87	3	NA	NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis

Table 4-' d.)

Groundwater R. emistry Results

for Regulated Units at Rocky Flats Plant

Well Number	Field Sample Number	Date Sampled	Qtr.	Americium 241	Cesium 137	Tritium
Landfill Alluvial Wells Downgradient						
0586	DRY	09/08/86		NA	NA	NA
0586	5-86-05-05-87	05/05/87	1	0.0 +/- 1.3 pc/l	NR	120 pc/l
0586	5-86-06-09-87	06/09/87	2	NR	NR	NR
0586	5-86-07-31-87	07/31/87	3	NR	NR	<540 pci/l
0786	DRY	09/29/86		NA	NA	NA
0786	DRY	08/10/87	3	NA	NA	NA
0786	07-86-02-01-88	02/01/88	1	NA	NA	NA
4087	DRY	08/10/87	3	NA	NA	NA
4087	DRY	02/01/88	1	NA	NA	NA
4287	GW4287	06/24/87	2	NA	NA	NA
4287	DRY	08/10/87	3	NA	NA	NA
4287	42-87-12-16-87	12/16/87	4	NA	NA	<220 pci/l
4287	42-87-02-04-88	02/04/88	1	NR	NR	<220 pci/l
5987	59-87-01-23-88	01/23/88	1	0.00 +/- 0.14 pci/l	NR	<220 pci/l
6087	60-87-01-23-88	01/23/88	1	0.00 +/- 0.10 pci/l	NR	<220 pci/l
6187	61-87-01-27-88	01/27/88	1	0.02 +/- 0.10 pci/l	NR	<220 pci/l
6287	62-87-01-26-88	01/26/88	1	0.00 +/- 0.16 pci/l	NR	NA
0686	DRY	09/08/86		NA	NA	NR
0686	6-86-05-13-87	05/13/87	1	NR	NR	NA
0686	6-86-06-09-87	06/09/87	2	NA	NA	NA
0686	6-86-08-10-87	08/10/87	3	NA	NA	NA
0686	08-86-02-01-88	02/01/88	1	NA	NA	1900 +/- 100 pci/l
6387	63-87-01-27-88	01/27/88	1	0.00 +/- 0.24 pci/l	NR	<210 pci/l
6487	64-87-01-29-88	01/29/88	1	0.00 +/- 0.71 pci/l	NR	<210 pci/l
6587	65-87-01-28-88	01/28/88	1	0.00 +/- 0.50 pci/l	NR	<210 pci/l
6687	66-87-01-29-88	01/29/88	1	0.00 +/- 0.50 pci/l	NR	<220 pci/l
6787	67-87-01-28-88	01/28/88	1	0.03 +/- 0.06 pci/l	NR	<220 pci/l
6887	68-87-01-28-88	01/28/88	1	0.00 +/- 0.09 pci/l	NR	NA
7087	DRY	02/03/88	1	NA	NA	<210 pci/l
7187	71-87-01-29-88	01/29/88	1	0.00 +/- 0.69 pci/l	NR	<210 pci/l
7287	72-87-01-28-88	01/28/88	1	0.00 +/- 0.11 pci/l	NR	NA
0486	DRY	08/28/86		NA	NA	NA
0486	DRY	08/10/87	3	NA	NA	

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis

Table 4-5 (cont'd.)

Groundwater Inorganic Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	CO_3	HCO_3	Chloride	Sulfate	pH	Fluoride	Nitrate-Nitrite Nitrogen
Landfill Alluvial Wells Upgradient										
1086	G1086108601	10/16/86		60 mg/l	16 mg/l	4.3 mg/l	17 mg/l	NR	NR	NR
1086	10-86-05-14-87	05/14/87	1	NR	30.0 mg/l	6.30 mg/l	42.0 mg/l	NR	NR	3.40 mg/l
1086	10-86-06-15-87	06/15/87	2	NR	27.5 mg/l	4.91 mg/l	40.0 mg/l	NR	NR	4.50 mg/l
1086	10-86-08-10-87	08/10/87	3	NR	30.2 mg/l	72.0 mg/l	36.0 mg/l	NR	NR	4.95 mg/l
1086	10-86-12-15-87	12/15/87	4	NR	47.1 mg/l	2.91 mg/l	49.0 mg/l	NR	NR	3.34 mg/l
1086	10-86-02-02-88	02/02/88	1	NR	40.5 mg/l	3.02 mg/l	23.8 mg/l	NR	NR	3.37 mg/l
4586	G4586108601	10/16/86		110 mg/l	12 mg/l	6.1 mg/l	14 mg/l	NR	NR	NR
4586	G4586108602	10/16/86		5 U mg/l	4.9 mg/l	5.9 mg/l	13 mg/l	NR	NR	NR
4586	45-86-05-15-87	05/14/87	1	NR	22.0 mg/l	4.90 mg/l	24.5 mg/l	NR	NR	0.56 mg/l
4586	45-86-06-12-87	06/12/87	2	NR	18.4 mg/l	9.30 mg/l	19.0 mg/l	NR	NR	0.51 mg/l
4586	45-86-08-14-87	08/14/87	3	NR	39.1 mg/l	6.39 mg/l	14.5 mg/l	NR	NR	0.75 mg/l
4586	45-86-09-30-87	09/30/87		NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4	NR	45.1 mg/l	6.5 mg/l	17.5 mg/l	NR	NR	1.02 mg/l
4586	45-86-10-01-87	10/01/87	4	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1	NR	37.3 mg/l	13.8 mg/l	34.2 mg/l	NR	NR	3.38 mg/l

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4 .'d.)

Groundwater Inorg Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Sulfide	Phosphate	Cyanide, Total	Hexavalent Chromium (Cr+6)	Total Dissolved Solids	Suspended Solids	% Solids
Landfill Alluvial Wells Upgradient										
1086	G1086108602	10/16/86		NR	NR	0.01 U mg/l	NR	140 mg/l	NR	NR
1086	10-86-05-14-87	05/14/87	1	NR	NR	1.0 U mg/l	NR	145 mg/l	NR	NR
1086	10-86-06-15-87	06/15/87	2	NR	NR	1.0 U mg/l	NR	161 mg/l	NR	NR
1086	10-86-08-10-87	08/10/87	3	NR	NR	1 U mg/l	NR	125 mg/l	NR	NR
1086	10-86-12-15-87	12/15/87	4	NR	NR	NR	NR	134 mg/l	NR	NR
1086	10-86-02-02-88	02/02/88	1	NR	NR	NR	NR	131 mg/l	NR	NR
4586	G4586108600	10/16/86		NR	NR	0.01 U mg/l	NR	180 mg/l	NR	NR
4586	G4586108602	10/16/86		NR	NR	0.01 U mg/l	NR	160 mg/l	NR	NR
4586	45-86-05-15-87	05/14/87	1	NR	NR	1.0 U mg/l	NR	143 mg/l	NR	NR
4586	45-86-06-12-87	06/12/87	2	NR	NR	1.0 U mg/l	NR	92.0 mg/l	NR	NR
4586	45-86-08-14-87	08/14/87	3	NR	NR	1 U mg/l	NR	124 mg/l	NR	NR
4586	45-86-09-30-87	09/30/87		NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4	NR	NR	NR	NR	125 mg/l	NR	NR
4586	45-86-10-01-87	10/01/87	4	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1	NR	NR	NR	NR	233 mg/l	NR	NR

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-5 [illegible].)

Groundwater Inorg[illegible] Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	CO3-	HCO3-	Chloride	Sulfate	pH	Fluoride	Nitrate-Nitrite Nitrogen
Landfill Alluvial Wells Downgradient										
0586	DRY	09/08/86		NA	NA	NA	NA	NA	NA	NA
0586	5-86-05-05-87	05/05/87	1	NR	366 mg/l	150 mg/l	1780 mg/l	NR	NR	2.75 mg/l
0586	5-86-06-09-87	06/09/87	2	NR	388 mg/l	264 mg/l	725 mg/l	NR	NR	1.26 mg/l
0586	5-86-07-31-87	07/31/87	3	NR	459 mg/l	270 mg/l	4600 mg/l	NR	NR	1.20 mg/l
0786	DRY	09/29/86		NA	NA	NA	NA	NA	NA	NA
0786	DRY	08/10/87	3	NA	NA	NA	NA	NA	NA	NA
0786	07-86-02-01-88	02/01/88	1	NA	NA	NA	NA	NA	NA	NA
4087	DRY	08/10/87	3	NA	NA	NA	NA	NA	NA	NA
4087	DRY	02/01/88	1	NA	NA	NA	NA	NA	NA	NA
4287	GW4287	06/24/87	2	NA	NA	NA	NA	NA	NA	NA
4287	DRY	08/10/87	3	NA	NA	NA	NA	NA	NA	NA
4287	42-87-12-16-87	12/16/87	4	NA	NA	NA	NA	NA	NA	NA
4287	42-87-02-04-88	02/04/88	1	NR	259 mg/l	13.9 mg/l	74.2 mg/l	NR	NR	0.02 U mg/l
5987	59-87-01-23-88	01/23/88	1	NR	306 mg/l	24.3 mg/l	31.8 mg/l	NR	NR	0.02 U mg/l
6087	60-87-01-23-88	01/23/88	1	NR	75.7 mg/l	4.33 mg/l	57.1 mg/l	NR	NR	2.62 mg/l
6187	61-87-01-27-88	01/27/88	1	NR	88.0 mg/l	2.87 mg/l	59.2 mg/l	NR	NR	2.58 mg/l
6287	62-87-01-26-88	01/26/88	1	NR	75.4 mg/l	3.89 mg/l	35.0 mg/l	NR	NR	2.55 mg/l
0686	DRY	09/08/86		NA	NA	NA	NA	NA	NA	NA
0686	6-86-05-13-87	05/13/87	1	NR	227 mg/l	826 mg/l	1710 mg/l	NR	NR	0.44 mg/l
0686	6-86-06-09-87	06/09/87	2	NA	NA	NA	NA	NA	NA	NA
0686	6-86-08-10-87	08/10/87	3	NA	NA	NA	NA	NA	NA	NA
0686	08-86-02-01-88	02/01/88	1	NA	NA	NA	NA	NA	NA	NA
6387	63-87-01-27-88	01/27/88	1	NR	392 mg/l	26.3 mg/l	54.5 mg/l	NR	NR	0.02 U mg/l
6487	64-87-01-29-88	01/29/88	1	NR	179 mg/l	19.9 mg/l	8.4 mg/l	NR	NR	0.02 mg/l
6587	65-87-01-28-88	01/28/88	1	NR	208 mg/l	6.38 mg/l	153 mg/l	NR	NR	2.00 mg/l
6687	66-87-01-29-88	01/29/88	1	NR	127 mg/l	4.50 mg/l	29.0 mg/l	NR	NR	3.22 mg/l
6787	67-87-01-28-88	01/28/88	1	NR	101 mg/l	4.32 mg/l	39.8 mg/l	NR	NR	1.81 mg/l
6887	68-87-01-28-88	01/28/88	1	NR	107 mg/l	5.03 mg/l	139 mg/l	NR	NR	2.12 mg/l
7087	DRY	02/03/88	1	NA	NA	NA	NA	NA	NA	NA
7187	71-87-01-29-88	01/29/88	1	NR	219 mg/l	2.15 mg/l	67.0 mg/l	NR	NR	1.02 mg/l
7287	72-87-01-28-88	01/28/88	1	NR	276 mg/l	8.42 mg/l	90.4 mg/l	NR	NR	0.33 mg/l
0486	DRY	08/28/86		NA	NA	NA	NA	NA	NA	NA
0486	DRY	08/10/87	3	NA	NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-! d.)

Groundwater Inorg Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Sulfide	Phosphate	Cyanide, Total	Hexavalent Chromium (Cr+6)	Total Dissolved Solids	Suspended Solids	% Solids
Landfill Alluvial Wells Lowngradient										
0586	DRY	09/08/86		NA	NA	NA	NA	NA	NA	NA
0586	5-86-05-05-87	05/05/87	1	NR	NR	1.0 U mg/l	NR	3517 mg/l	NR	NR
0586	5-86-06-09-87	06/09/87	2	NR	NR	1.0 U mg/l	NR	7363 mg/l	NR	NR·
0586	5-86-07-31-87	07/31/87	3	NR	NR	1 U mg/l	NR	6747 mg/l	NR	NR
0786	DRY	09/29/86		NA	NA	NA	NA	NA	NA	NA
0786	DRY	08/10/87	3	NA	NA	NA	NA	NA	NA	NA
0786	07-86-02-01-88	02/01/88	1	NA	NA	NA	NA	NA	NA	NA
4087	DRY	08/10/87	3	NA	NA	NA	NA	NA	NA	NA
4087	DRY	02/01/88	1	NA	NA	NA	NA	NA	NA	NA
4287	GW4287	06/24/87	2	NA	NA	NA	NA	NA	NA	NA
4287	DRY	08/10/87	3	NA	NA	NA	NA	NA	NA	NA
4287	42-87-12-16-87	12/16/87	4	NA	NA	NA	NA	NA	NA	NA
4287	42-87-02-04-88	02/04/88	1	NR	NR	NR	NR	355 mg/l	NR	NR
5987	59-87-01-23-88	01/23/88	1	NR	NR	NR	NR	406 mg/l	NR	NR
6087	60-87-01-23-88	01/23/88	1	NR	NR	NR	NR	160 mg/l	NR	NR
6187	61-87-01-27-88	01/27/88	1	NR	NR	NR	NR	153 mg/l	NR	NR
6287	62-87-01-26-88	01/26/88	1	NR	NR	NR	NR	154 mg/l	NR	NR
0686	DRY	09/08/86		NA	NA	NA	NA	NA	NA	NA
0686	6-86-05-13-87	05/13/87	1	NR	NR	1.0 U mg/l	NR	4542 mg/l	NR	NR
0686	6-86-06-09-87	06/09/87	2	NA	NA	NA	NA	NA	NA	NA
0686	6-86-08-10-87	08/10/87	3	NA	NA	NA	NA	NA	NA	NA
0686	08-86-02-01-88	02/01/88	1	NA	NA	NA	NA	NA	NA	NA
6387	63-87-01-27-88	01/27/88	1	NR	NR	NR	NR	519 mg/l	NR	NR
6487	64-87-01-29-88	01/29/88	1	NR	NR	NR	NR	255 mg/l	NR	NR
6587	65-87-01-28-88	01/28/88	1	NR	NR	NR	NR	491 mg/l	NR	NR
6687	66-87-01-29-88	01/29/88	1	NR	NR	NR	NR	405 mg/l	NR	NR
6787	67-87-01-28-88	01/28/88	1	NR	NR	NR	NR	191 mg/l	NR	NR
6887	68-87-01-28-88	01/28/88	1	NR	NR	NR	NR	226 mg/l	NR	NR
7087	DRY	02/03/88	1	NA	NA	NA	NA	NA	NA	NA
7187	71-87-01-29-88	01/29/88	1	NR	NR	NR	NR	262 mg/l	NR	NR
7287	72-87-01-28-88	01/28/88	1	NR	NR	NR	NR	395 mg/l	NR	NR
0486	DRY	08/28/86		NA	NA	NA	NA	NA	NA	NA
0486	DRY	08/10/87	3	NA	NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-5 (Cont'd.)

Groundwater Meta. esults for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Silver (Ag), total	Aluminum (Al), total	Arsenic (As), total	Barium (Ba), total	Beryllium (Be), total	Calcium (Ca), total	Cadmium (Cd), total	Colbalt (Co), total	Chromium (Cr), total	Cesium (Cs), total
Landfill Alluvial Wells Upgradient														
1086	G1086108б0	10/16/86		mg/l	0.019	36.6	0.002 U	0.340	0.026	22.1	0.005 U	0.050 U	0.010	0.150 U
1086	10-86-05-14-87	05/14/87	1	mg/l	0.0076 U	0.1323	0.01 U	0.0326	0.005 U	25.6217	0.005 U	0.0220 U	0.0100 U	0.2 U
1086	10-86-06-15-87	06/15/87	2	mg/l	0.0076 U	0.0290 U	0.01 U	0.0330	0.005 U	20.1122	0.005 U	0.0220 U	0.0105	0.2 U
1086	10-86-08-10-87	08/10/87	3	mg/l	0.0076 U	0.0320	0.005 U	0.0805	0.005 U	20.5573	0.001 U	0.0220 U	0.0188	0.02 U
1086	10-86-12-15-87	12/15/87	4	mg/l	0.0076 U	0.1504	0.005 U	0.0838	0.005 U	16.1526	0.0008 J	0.0220 U	0.0100 U	0.02 U
1086	10-86-02-02-88	02/02/88	1	mg/l	0.0076 U	0.0290 U	0.005 U	0.0722	0.005 U	17.0370	0.001 U	0.0220 U	0.0214	0.02 U
4586	G4586108б0	10/16/86		mg/l	0.010 U	0.480	0.002 U	0.160	0.011	26.2	0.005 U	0.050 U	0.010 U	0.150 U
4586	G458610862	10/16/86		mg/l	0.010 U	0.550	0.002 U	0.150	0.007	25.5	0.005 U	0.050 U	0.010 U	0.150 U
4586	45-86-05-15-87	05/14/87	1	mg/l	0.0076 U	0.1786	0.0100 U	0.0308	0.005 U	11.5612	0.0050 U	0.0220 U	0.0100 U	0.2 U
4586	45-86-06-12-87	06/12/87	2	mg/l	0.0076 U	0.0405	0.01 U	0.0265	0.005 U	9.0966	0.005 U	0.0220 U	0.0100 U	0.2 U
4586	45-86-08-14-87	08/14/87	3	mg/l	0.0076 U	0.0727	0.005 U	0.0615	0.005 U	10.0692	0.001 U	0.0220 U	0.0115	0.02 U
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4	mg/l	0.0076 U	0.0336	0.005 U	0.0556	0.005 U	12.8262	0.001 U	0.0220 U	0.0100 U	0.02 U
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1	mg/l	0.0085	0.0443	0.005 U	0.1067	0.005 U	27.8264	0.001 U	0.0220 U	0.0191	0.02 U

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-[illegible] d.)

Groundwater Meta[illegible] esults for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Copper (Cu), total	Iron (Fe), total	Mercury (Hg), total	Potassium (K), total	Lithium (Li), total	Magnesium (Mg), total	Manganese (Mn), total	Molybdenum (Mo), total	Sodium (Na), total	Nickel (Ni), total
Landfill Alluvial Wells Upgradient														
1086	G108610860	10/16/86		mg/l	0.024	28.2	0.00056	12.9	NR	7.88	0.634	0.100 U	12.2	0.040 U
1086	10-86-05-14-87	05/14/87	1	mg/l	0.0063 U	0.0469	0.0002 U	5.0 U	NR	4.9638	0.1339	0.0220 U	13.2611	0.0370 U
1086	10-86-06-15-87	06/15/87	2	mg/l	0.0080	0.0481	0.0002 U	5.0 U	NR	3.7433	0.1113	0.0220 U	9.7672	0.0370 U
1086	10-86-08-10-87	08/10/87	3	mg/l	0.0063 U	0.0640	0.0002 U	5.9	NR	4.0182	0.0979	0.0220 U	13.7014	0.0370 U
1086	10-86-12-15-87	12/15/87	4	mg/l	0.0086	0.1329	0.0002 U	0.9	0.1 U	3.4896	0.0901	0.0220 U	12.9361	0.0370 U
1086	10-86-02-02-88	02/02/88	1	mg/l	0.0070	0.0868	0.0002 U	0.6	0.1 U	3.2011	0.0835	0.0220 U	9.9138	0.0693
4586	G458610860	10/16/86		mg/l	0.020 U	0.252	0.00021	0.623	NR	5.90	0.079	0.100 U	13.4	0.040 U
4586	G458610862	10/16/86		mg/l	0.020 U	0.242	0.0016	0.540	NR	5.40	0.091	0.100 U	13.9	0.040 U
4586	45-86-05-15-87	05/14/87	1	mg/l	0.0063 U	0.0948	0.0002 U	5.0 U	NR	2.6072	0.0141	0.0220 U	7.3332	0.0370 U
4586	45-86-06-12-87	06/12/87	2	mg/l	0.0063 U	0.0311	0.0002 U	5.0 U	NR	2.1295	0.0051 U	0.0220 U	6.5707	0.0370 U
4586	45-86-08-14-87	08/14/87	3	mg/l	0.0068 U	0.0495	0.0002 U	0.6	NR	2.3749	0.0062	0.0220 U	10.7756	0.0370 U
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4	mg/l	0.0063 U	0.0143	0.0002 U	0.67 -	0.1 U	3.3490	0.0051 U	0.0220 U	10.8467	0.0370 U
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1	mg/l	0.0437	0.0999	0.0002	5.2	0.1 U	5.4896	0.5217	0.0220 U	24.6325	0.1425

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4 (Cont'd.)

Groundwater Metal Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Lead (Pb), total	Antimony (Sb), total	Selenium (Se), total	Strontium (Sr), total	Thallium (Tl), total	Vanadium (V), total	Zinc (Zn), total
Landfill Alluvial Wells Upgradient											
1086	G1086l0860	10/16/86		mg/l	0.005 U	0.050 U	0.002 U	0.238	0.010 U	0.057	0.055
1086	10-86-05-14-87	05/14/87	1	mg/l	0.005 U	0.0600 U	0.0050 U	0.1292	0.01 U	0.0240 U	0.02 U
1086	10-86-06-15-87	06/15/87	2	mg/l	0.009	0.06 U	0.005 U	0.1014	0.01 U	0.0240 U	0.0295
1086	10-86-08-10-87	08/10/87	3	mg/l	0.005 U	0.02 U	0.005 U	0.1145	0.01 U	0.0240 U	0.0581
1086	10-86-12-15-87	12/15/87	4	mg/l	0.004 J	0.02 U	0.005 U	0.0975	0.01 U	0.0240 U	0.0200 U
1086	10-86-02-02-88	02/02/88	1	mg/l	0.005 U	0.02 U	0.005 U	0.0971	0.01 U	0.0292	0.0884
4586	G4586l0860	10/16/86		mg/l	0.005 U	0.050 U	0.002 U	0.190	0.010 U	0.025 U	0.006
4586	G4586l0862	10/16/86		mg/l	0.005 U	0.050 U	0.002 U	0.193	0.010 U	0.025 U	0.005 U
4586	45-86-05-15-87	05/14/87	1	mg/l	0.0050 U	0.06 U	0.005 U	0.0633	0.0100 U	0.0240 U	0.02 U
4586	45-86-06-12-87	06/12/87	2	mg/l	0.011	0.06 U	0.005 U	0.0550	0.01 U	0.0240 U	0.0200 U
4586	45-86-08-14-87	08/14/87	3	mg/l	0.005 U	0.02 U	0.005 U	0.0617	0.01 U	0.0240 U	0.0498
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4	mg/l	0.002 J	0.011 J	0.005 U	0.0847	0.01 U	0.0334	0.0200 U
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1	mg/l	0.005 U	0.02 U	0.005 U	0.2273	0.01 U	0.0240 U	0.4270

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-5 ([illegible] .)

Groundwater Meta [illegible] sults for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Silver (Ag), total	Aluminum (Al), total	Arsenic (As), total	Barium (Ba), total	Beryllium (Be), total	Calcium (Ca), total	Cadmium (Cd), total	Colbalt (Co), total	Chromium (Cr), total	Cesium (Cs), total
Landfill Alluvial Wells Downgradient														
0586	DRY	09/08/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0586	5-86-05-05-87	05/05/87	1	mg/l	0.0076 U	0.0290 U	0.01 U	0.0416	0.005 U	325.9938	0.005 U	0.0220 U	0.0100 U	0.2 U
0586	5-86-06-09-87	06/09/87	2	mg/l	0.0076 U	0.4102	0.01 U	0.0758	0.005 U	31.6307	0.005 U	0.0220 U	0.0120	0.2 U
0586	5-86-07-31-87	07/31/87	3	mg/l	0.0076 U	0.0372	0.005 U	0.0656	0.005 U	473.0916	0.001 U	0.0220 U	0.0100 U	0.02 U
0786	DRY	09/29/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0786	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0786	07-86-02-01-88	02/01/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4087	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4087	DRY	02/01/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4287	GW4287	06/24/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4287	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4287	42-87-12-16-87	12/16/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4287	42-87-02-04-88	02/04/88	1	mg/l	0.0076 U	0.0463	0.005 U	0.1437	0.005 U	71.3661	0.001 U	0.0220 U	0.0100 U	0.02 U
5987	59-87-01-23-88	01/23/88	1	mg/l	0.0076 U	0.0737	0.005 U	0.2532	0.005 U	78.5587	0.001	0.0220 U	0.0154	0.02 U
6087	60-87-01-23-88	01/23/88	1	mg/l	0.0076 U	0.0769	0.005 U	0.1434	0.005 U	26.9666	0.001 U	0.0220 U	0.0100 U	0.02 U
6187	61-87-01-27-88	01/27/88	1	mg/l	0.0076 U	0.1453	0.005 U	0.1307	0.005 U	24.2757	0.001 U	0.0220 U	0.0282	0.02 U
6287	62-87-01-26-88	01/26/88	1	mg/l	0.0076 U	0.1130	0.005 U	0.1538	0.005 U	26.8479	0.001 U	0.0220 U	0.0193	0.02 U
0686	DRY	09/08/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0686	6-86-05-13-87	05/13/87	1	mg/l	0.0076 U	0.0554	0.01 U	0.0463	0.005 U	443.5691	0.005 U	0.0220 U	0.0100 U	0.2 U
0686	6-86-06-09-87	06/09/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0686	6-86-08-10-87	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0686	08-86-02-01-88	02/01/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6387	63-87-01-27-88	01/27/88	1	mg/l	0.0076 U	0.0506	0.005 U	0.2462	0.005 U	122.5689	0.001 U	0.0220 U	0.0296	0.02 U
6487	64-87-01-29-88	01/29/88	1	mg/l	0.0085	0.0353	0.005 U	0.1826	0.005 U	47.2474	0.001 U	0.0313	0.0136	0.02 U
6587	65-87-01-28-88	01/28/88	1	mg/l	0.0076 U	0.0346	0.005 U	0.1291	0.005 U	74.4528	0.001 U	0.0220 U	0.0131	0.02 U
6687	66-87-01-29-88	01/29/88	1	mg/l	0.0076 U	0.0769	0.005 U	0.1020	0.005 U	34.0248	0.001 U	0.0220 U	0.0236	0.02 U
6787	67-87-01-28-88	01/28/88	1	mg/l	0.0076 U	0.0290 U	0.005 U	0.1034	0.005 U	40.1314	0.001	0.0220 U	0.0114	0.02 U
6887	68-87-01-28-88	01/28/88	1	mg/l	0.0076 U	0.0290	0.005 U	0.1528	0.005 U	32.4063	0.001 U	0.0220 U	0.0100 U	0.02 U
7087	DRY	02/03/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7187	71-87-01-29-88	01/29/88	1	mg/l	0.0076 U	0.0308	0.005 U	0.0841	0.005 U	71.2977	0.001 U	0.0220 U	0.0135	0.02 U
7287	72-87-01-28-88	01/28/88	1	mg/l	0.0076 U	0.0516	0.005 U	0.1574	0.005 U	88.9694	0.001 U	0.0220 U	0.0111	0.02 U
0486	DRY	08/28/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0486	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4- it'd.)
Groundwater Meta. .esults for Landfill
Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Copper (Cu), total	Iron (Fe), total	Mercury (Hg), total	Potassium (K), total	Lithium (Li), total	Magnesium (Mg), total	Manganese (Mn), total	Molybdenum (Mo), total	Sodium (Na), total	Nickel (Ni), total
Landfill Alluvial Wells Downgradient														
0586	DRY	09/08/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0586	5-86-05-05-87	05/05/87	1	mg/l	0.0799	0.0069 U	0.0002 U	5.0	NR	264.1889	0.0624	0.0220 U	720.3239	0.1912
0586	5-86-06-09-87	06/09/87	2	mg/l	0.0063 U	0.4246	0.0002 U	5.7	NR	6.4399	0.0234	0.0220 U	21.7350	0.0370 U
0586	5-86-07-31-87	07/31/87	3	mg/l	0.0154	0.0069 U	0.0002 U	3.1	NR	291.7351	0.0479	0.0291	1179.3182	0.1751
0786	DRY	09/29/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0786	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0786	07-86-02-01-88	02/01/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4087	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4087	DRY	02/01/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4287	GW4287	06/24/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4287	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4287	42-87-12-16-87	12/16/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4287	42-87-02-04-88	02/04/88	1	mg/l	0.0065	0.4066	0.0002 U	9.4	0.05 J	12.9761	0.5674	0.0220 U	52.5685	0.0370 U
5987	59-87-01-23-88	01/23/88	1	mg/l	0.0154	0.1716	0.0002 U	11	0.1 U	14.8116	2.1310	0.0220 U	31.5072	0.2035
6087	60-87-01-23-88	01/23/88	1	mg/l	0.0365	0.0813	0.0002 U	1.0	0.1 U	4.7603	0.3136	0.0220 U	14.1688	0.0370 U
6187	61-87-01-21-88	01/21/88	1	mg/l	0.0085	0.1865	0.0002 U	2.1	0.1 U	4.5329	0.2702	0.0220 U	14.9011	0.0370 U
6287	62-87-01-26-88	01/26/88	1	mg/l	0.0118	0.1015	0.0002 U	3.0	0.1 U	4.8600	0.4100	0.0220 U	13.4639	0.0416
0686	DRY	09/08/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0686	6-86-05-13-87	05/13/87	1	mg/l	0.0063 U	0.0069 U	0.0002 U	10.9	NR	177.7157	1.2989	0.0220 U	801.8515	1.4027
0686	6-86-06-09-87	06/09/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0686	6-86-08-10-87	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0686	08-86-02-01-88	02/01/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6387	63-87-01-27-88	01/27/88	1	mg/l	0.0105	0.1137	0.0002 U	3.8	0.1 U	15.3287	0.6425	0.0220 U	33.6016	0.0370 U
6487	64-87-01-29-88	01/29/88	1	mg/l	0.0568	0.0471	0.0002 U	4.2	0.1 U	8.2194	1.2001	0.3551	18.7309	0.0444
6587	65-87-01-28-88	01/28/88	1	mg/l	0.0063 U	0.0401	0.0002 U	6.2	0.1 U	13.2047	1.0484	0.0220 U	71.3146	0.0370 U
6687	66-87-01-29-88	01/29/88	1	mg/l	0.0545	0.1182	0.0002	6.1	0.1 U	7.2507	0.1784	0.0299	94.6908	0.1863
6787	67-87-01-28-88	01/28/88	1	mg/l	0.0063 U	0.0419	0.0002 U	4.9	0.1 U	5.5284	0.6670	0.0220 U	17.3672	0.0748
6887	68-87-01-28-88	01/28/88	1	mg/l	0.0063 U	0.9492	0.0002 U	3.0	0.1 U	5.3604	1.6145	0.0220 U	19.3733	0.0370
7087	DRY	02/03/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7187	71-87-01-29-88	01/29/88	1	mg/l	0.0070	0.0344	0.0002	1.7	0.1 U	9.3802	0.0590	0.0220 U	9.5292	0.0370 U
7287	72-87-01-28-88	01/28/88	1	mg/l	0.0069	0.0344	0.0002 U	3.1	0.1 U	16.7782	0.5105	0.0220 U	23.4236	0.0370 U
0486	DRY	08/28/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0486	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4 (cont'd.)

Groundwater Metals Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Lead (Pb), total	Antimony (Sb), total	Selenium (Se), total	Strontium (Sr), total	Thallium (Tl), total	Vanadium (V), total	Zinc (Zn), total
Landfill Alluvial Wells Downgradient											
0586	DRY	09/08/86			NA	NA	NA	NA	NA	NA	NA
0586	5-86-05-05-87	05/05/87	1	mg/l	0.005 U	0.0600 U	0.011	5.2430	0.01 U	0.0240 U	0.02 U
0586	5-86-06-09-87	06/09/87	2	mg/l	0.005 U	0.06 U	0.005 U	0.1721	0.01 U	0.0240 U	0.0236
0586	5-86-07-31-87	07/31/87	3	mg/l	0.005	0.007 J	0.009	9.4688	0.01 U	0.0240 U	0.0212
0786	DRY	09/29/86			NA	NA	NA	NA	NA	NA	NA
0786	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA
0786	07-86-02-01-88	02/01/88	1		NA	NA	NA	NA	NA	NA	NA
4087	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA
4087	DRY	02/01/88	1		NA	NA	NA	NA	NA	NA	NA
4287	GW4287	06/24/87	2		NA	NA	NA	NA	NA	NA	NA
4287	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA
4287	42-87-12-16-87	12/16/87	4		NA	NA	NA	NA	NA	NA	NA
4287	42-87-02-04-88	02/04/88	1	mg/l	0.005 U	0.02 U	0.005 U	1.2777	0.01 U	0.0240 U	0.0352
5987	59-87-01-23-88	01/23/88	1	mg/l	0.010	0.02 U	0.002 J	0.6235	0.01 U	0.0240 U	0.5840
6087	60-87-01-23-88	01/23/88	1	mg/l	0.005 U	0.02 U	0.005 U	0.1399	0.01 U	0.0240 U	0.2418
6187	61-87-01-27-88	01/27/88	1	mg/l	0.005 U	0.02 U	0.005 U	0.1619	0.01 U	0.0264	0.0755
6287	62-87-01-26-88	01/26/88	1	mg/l	0.005 U	0.02 U	0.005 U	0.1716	0.01 U	0.0240 U	0.0714
0686	DRY	09/08/86			NA	NA	NA	NA	NA	NA	NA
0686	6-86-05-13-87	05/13/87	1	mg/l	0.005 U	0.0600 U	0.089	5.1181	0.01 U	0.0240 U	0.02 U
0686	6-86-06-09-87	06/09/87	2		NA	NA	NA	NA	NA	NA	NA
0686	6-86-08-10-87	08/10/87	3		NA	NA	NA	NA	NA	NA	NA
0686	08-86-02-01-88	02/01/88	1		NA	NA	NA	NA	NA	NA	NA
6387	63-87-01-27-88	01/27/88	1	mg/l	0.005 U	0.02 U	0.005 U	0.6899	0.01 U	0.0240 U	0.0608
6487	64-87-01-29-88	01/29/88	1	mg/l	0.005 U	0.02 U	0.005 U	0.3320	0.01 U	0.0572	0.0486
6587	65-87-01-28-88	01/28/88	1	mg/l	0.005 U	0.02 U	0.005 U	0.5041	0.01 U	0.0240 U	0.0598
6687	66-87-01-29-88	01/29/88	1	mg/l	0.005 U	0.02 U	0.005 U	0.3011	0.01 U	0.1004	0.4714
6787	67-87-01-28-88	01/28/88	1	mg/l	0.005 U	0.02 U	0.005 U	0.2425	0.01 U	0.0240 U	0.1893
6887	68-87-01-28-88	01/28/88	1	mg/l	0.005 U	0.02 U	0.005 U	0.1964	0.01 U	0.0240 U	0.1062
7087	DRY	02/03/88	1		NA	NA	NA	NA	NA	NA	NA
7187	71-87-01-29-88	01/29/88	1	mg/l	0.005 U	0.02 U	0.005 U	0.4217	0.01 U	0.0364	0.0572
7287	72-87-01-28-88	01/28/88	1	mg/l	0.005 U	0.02 U	0.005 U	0.5986	0.01 U	0.0240 U	0.0353
0486	DRY	08/28/86			NA	NA	NA	NA	NA	NA	NA
0486	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-5 ([illegible] .)

Groundwater Pestici[illegible]B Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Alpha-BHC	Beta BHC	Delta-BHC	Gamma-BHC	Heptachlor	Aldrin	Heptachlor Epoxide	Endosulfan I	Dieldrin	4,4 DDT
Landfill Alluvial Wells Upgradient														
1086	G108610860	10/16/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-05-14-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-06-15-87	06/15/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-08-10-87	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-12-15-87	12/15/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-02-02-88	02/02/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	G458610860	10/16/86		ug/l	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.1 U	0.1 U
4586	G458610862	10/16/86		ug/l	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.1 U	0.1 U
4586	45-86-05-15-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-06-12-87	06/12/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-08-14-87	08/14/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4- l'd.)

Groundwater Pestici :B Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Endrin	Endosulfan II	4,4'-DDD	Endosulfan Sulfate	4,4'-DDT	Methoxychlor	Endrin Ketone	Chlordane	Toxaphene	Aroclor-1016
Landfill Alluvial Wells upgradient														
1086	G1086108G0	10/16/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-05-14-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-06-15-87	06/15/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-08-10-87	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-12-15-87	12/15/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-02-02-88	02/02/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	G458610860	10/16/86		ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.5 U	0.1 U	0.5 U	1 U	0.5 U
4586	G458610862	10/16/86		ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.5 U	0.1 U	0.5 U	1 U	0.5 U
4586	45-86-05-15-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-06-12-87	06/12/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-08-14-87	08/14/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR = Analyte not reported
NA = Insufficient water in well for analysis
U = Analyzed but not detected
J = Present below detection limit
B = Present in laboratory blank

Table 4-5 ([illegible])

Groundwater Pestici[illegible]CB Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Aroclor-1221	Aroclor-1232	Aroclor-1242	Aroclor-1248	Aroclor-1254	Aroclor-1260
Landfill Alluvial Wells Upgradient										
1086	G108610860	10/16/86			NA	NA	NA	NA	NA	NA
1086	10-86-05-14-87	05/14/87	1		NA	NA	NA	NA	NA	NA
1086	10-86-06-15-87	06/15/87	2		NA	NA	NA	NA	NA	NA
1086	10-86-08-10-87	08/10/87	3		NA	NA	NA	NA	NA	NA
1086	10-86-12-15-87	12/15/87	4		NA	NA	NA	NA	NA	NA
1086	10-86-02-02-88	02/02/88	1		NA	NA	NA	NA	NA	NA
4586	G458610860	10/16/86		ug/l	0.5 U	0.5 U	0.5 U	0.5 U	1 U	1 U
4586	G458610862	10/16/86		ug/l	0.5 U	0.5 U	0.5 U	0.5 U	1 U	1 U
4586	45-86-05-15-87	05/14/87	1		NA	NA	NA	NA	NA	NA
4586	45-86-06-12-87	06/12/87	2		NA	NA	NA	NA	NA	NA
4586	45-86-08-14-87	08/14/87	3		NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4		NA	NA	NA	NA	NA	NA
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1		NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

During the 1986 drilling program, two ground-water monitor well pairs were installed at the Present Landfill. One pair consisting of one alluvial well (10-86) and one bedrock well (9-86) were placed upgradient of the landfill. The second well pair was placed downgradient of the landfill (bedrock well 8-86 and alluvial well 7-86) to monitor ground-water quality. Additional alluvial wells, 6-86 and 5-86, are located downgradient of the landfill in the unnamed tributary of North Walnut Creek.

In 1987, additional wells were installed to characterize the landfill and determine the effectiveness of the collection systems described in Section 4.2.1.2. An additional upgradient alluvial well was installed immediately west of the landfill (58-87). Eight wells were placed across the landfill collection system (59-87, 60-87, 61-87, 62-87, 63-87, 64-87, 65-87, and 66-87). Wells 67-87, 68-87, and 71-87 were positioned to monitor the effectiveness of the north slurry trench, whereas, wells 70-87 and 72-87 were installed to determine the effectiveness of the south slurry trench. Three wells were installed downgradient of the landfill pond embankment to monitor ground-water quality leaving the landfill area (alluvial wells 40-87 and 42-87 and bedrock well 41-87BR).

Two new alluvial wells, 40-87 and 70-87, were dry during the first quarter, 1988 sampling effort, therefore, no analytical data are available at this time. Three additional wells, 64-87, 66-87, and 71-87, were sampled for volatile organic compounds (VOC); however, the holding times expired before the samples were analyzed. Therefore, no VOC data are available for these three wells.

-- <u>Establishment of Ground-Water Quality Criteria</u>

The upgradient ground-water chemistry will be the basis for assessing impacts to ground water from the landfill. Table 4-6 provides the analyte concentration ranges observed in ground water at alluvial and bedrock wells located immediately upgradient of the landfill. As shown in the table, some unusually high analyte concentrations seen in the data set have not been considered in establishing the upgradient analyte concentration ranges. These high values are considered outliers that are likely not representative of upgradient alluvial ground-water chemistry.

The assessment provided here is qualitative in nature, its purpose being the identification of obvious impacts of the landfill on ground-water quality. The reader is referred to Section E of the Post Closure Care Permit Application for a discussion of proposed monitoring to achieve compliance with 40 CFR 265, Subpart F. Although the current monitoring program at the landfill was not designed specifically to satisfy RCRA requirements, many of the analytes measured are those required for routine monitoring under 265.92(b), and assessment monitoring under 265.93(a). Parameters for routine monitoring included in the monitoring program are the Safe Drinking Water Act (SDWA) metals, chloride, iron, manganese, sodium, sulfate, pH, and specific conductance. Assessment monitoring parameters are Appendix VIII hazardous waste constituents expected in the unit. Many of the HSL volatiles are Appendix VIII hazardous waste constituents that could have been disposed of and released from the facility. The radionuclides, although not Appendix VIII hazardous constituents, have been analyzed because they may be possible constituents of waste disposed at the landfill. Other parameters analyzed are for general inorganic characterization of the ground water.

TABLE 4-6

UPGRADIENT GROUND-WATER CHEMISTRY* AND GROUND-WATER QUALITY CRITERIA

Parameter	Upgradient Alluvial Ground-Water Chemistry Concentration Range (mg/l)	Upgradient Bedrock** Ground-Water Chemistry Concentration Range (mg/l)	Ground-Water Quality Criteria
METALS			
+ Silver (Ag)	.0076U-.019[1]	.0076U	.05
Aluminum (Al)	.029U-.179[1]	.029U-.055	5
+ Arsenic (As)	.01U	.01U-.015	.05
+ Barium (Ba)	.026-.340	.028-.160	1
++ Beryllium (Be)	.005U-.026	.005U	.1
+ Cadmium (Cd)	.005U	.005U	.01
Cobalt (Co)	.05U	.022U	.05
+ Chromium (Cr)	.01U-.02	.01U-.02	.05**
Cesium (Cs)	0.2U	.2U	NA
Copper (Cu)	.020U-.044[2]	.02U-.026	1
Iron (Fe)	.031-.252[2]	.013-.227	.3
+ Mercury (Hg)	.0002U-.0016	.0002U-.0002	.002
Lithium (Li)	.1U	.1U	2.5
Manganese (Mn)	.005U-.634	.013-.034	.05
Molybdenum (Mo)	.1U	.1U	.1
++ Nickel (Ni)	.037U-.142	.037U	.2
+ Lead (Pb)	.005U-.011	.005U-.025	.05
++ Antimony (Sb)	.06U	.06U	NA
+ Selenium (Se)	.005U	.005U	.01
Strontium (Sr)	.06-.24	.18-.28	NA
++ Thallium (Tl)	.01U	.01U	NA
Vanadium (V)	.025U-.057	.025U-.030	.1
Zinc	.02U-.43	.02U-.24	5
MAJOR IONS			
Calcium	9-28	21-26	NA
Magnesium	2-8	5-6	NA
Potassium	5U-13	5U	NA
Sodium	7-25[3]	53-72	NA
Chloride	4-14[3]	8-13[5]	250
Sulfate	13-49	3-15[5]	250
Bicarbonate	18-97	172-205	NA
Nitrate-N	0.5-5	.2U	10
Cyanide	1U	1U	NA
Total Dissolved Solids	92-233	217-350	400

TABLE 4-6
(CONTINUED)

UPGRADIENT GROUND-WATER CHEMISTRY*
AND GROUND-WATER QUALITY CRITERIA

E

Parameter	Upgradient Alluvial Ground-Water Chemistry Concentration Range (mg/l)	Upgradient Bedrock Ground-Water Chemistry Concentration Range (mg/l)	Ground-Water Quality Criteria
RADIONUCLIDES (pCi/l)			
Gross Alpha	<MDA - 249(15)	<MDA - 160(100)	15
Gross Beta	<MDA - 250(40)	<MDA - 220(60)	50
Plutonium 239, 240	<MDA - .106(.062)	<MDA	40
Americium 241	<MDA	<MDA	4 ***
Uranium 233, 234	<MDA - 15(2)	<MDA - 3.0(.5)	40***
Uranium 238	<MDA - 16(2)	<MDA - 5.3(2)	40
Strontium 89, 90	<MDA - 9.3	<MDA**** - 1.03	8
Tritium	<MDA - 330	<MDA	20,000

1 eliminating 36.6 mg/l as an outlier
2 eliminating 28.2 mg/l as an outlier
3 eliminating 72 mg/l as an outlier
4 eliminating 4.7 (1.8) pCi/l as an outlier
5 eliminating 151 mg/l as an outlier

* Based on data from wells 10-86, 45-86, and 58-87 for alluvial ground water and well 9-86 for bedrock ground water.
** Not available.
*** Total uranium.
**** MDA--Maximum Detectable Activity.
+ SDWA Metal
+ Appendix VIII hazardous constituent that is not an SDWA metal.

A ground-water protection standard is not defined for interim status regulated units under 40 CFR 265; however, regulations at 40 CFR 264, Subpart F, have been used as a framework to examine the ground-water quality at the landfill. The ground-water protection standard defined at 40 CFR 264.94 specifies background levels for hazardous constituents or SDWA drinking water standards for the SDWA metals (which are also hazardous constituents). The SDWA drinking water standards, as well as standards for other metals, inorganics, and radionuclides which are not hazardous constituents are shown in Table 4-6. The concentrations for major ions and non-SDWA metals are the Colorado Department of Health (CDH) ground-water standards for protection of human health (or protection of agriculture if human health standards are not available). Because the ground water in the vicinity of the landfill has not been classified by the State, these standards are not enforceable. The plutonium and americium concentrations are proposed drinking water standards (51 FR 34859). The uranium concentration is a CDH surface water standard [5 CCR 1002-8, Section 3.8.5(3)]. All other radionuclide standards are SDWA maximum contaminant levels. These analyte concentrations have been termed ground-water quality criteria, and are used only to preliminarily assess the public health significance of the ground-water quality.

-- <u>General Observations</u>

As shown in Appendix C, with few exceptions, HSL volatiles did not occur above detection limits. The only exceptions are the random occurrences of low concentrations [generally less than 10 milligrams per liter (ug/l)] of methylene chloride, acetone, methylethyl ketone, and carbon tetrachloride(CCL_4) in both upgradient and downgradient wells. For any single well, the occurrences are infrequent, the balance of the data showing the analytes non-detectable. Therefore, organic contamination is not an issue at the Present Landfill and is not discussed further.

With the exception of tritium, all radionuclide concentrations in ground water downgradient of the landfill were within ranges established for upgradient conditions. At well 63-87, located within the landfill, tritium was 1900(100) picoCuries (pCi/l), whereas upgradient ground-water tritium concentrations are below the minimum detectable activity (220 pCi/l). This tritium concentration likely reflects the known historical disposal of tritium in the landfill. The concentration is, however, below the proposed ground-water quality criterion. Tritium does not occur above the MDA elsewhere in ground water downgradient of the landfill.

As discussed in the next section, upgradient gross alpha, gross beta, and strontium 90 concentrations exceed the proposed ground-water quality criteria. This only occurs for gross alpha in downgradient ground-water, and occurs infrequently and at concentrations near the proposed ground-water quality criterion (15 pCi/l). These are the only findings with respect to radionuclides at the Present Landfill, and therefore, radionuclide concentrations downgradient of the landfill are not discussed further.

4.2.1.5 UPGRADIENT ALLUVIAL GROUND-WATER QUALITY

Major Ion Chemistry

All major ion concentrations are below the ground-water quality criteria. The concentration ranges suggest variability exists generally on the order of a factor of two or three.

Metals

With the exception of manganese, trace metal concentrations in upgradient alluvial ground water are below the proposed ground-water quality criteria. Manganese, at times, exceeds the proposed ground-water quality criteria by a factor of ten. Concentrations can vary considerably over time for many of the metals.

Radionuclides

The radionuclide concentrations in the upgradient alluvial ground water are below the proposed ground-water quality criteria except for gross alpha, gross beta, and strontium 90. Concentrations of gross alpha range from less than the MDA to 249(15) pCi/l. Gross beta concentrations range from less than the MDA to 250(40) pCi/l. Strontium 90 was 9.3 pCi/l in well 10-86. The proposed ground-water quality criteria for gross alpha, gross beta, and strontium 90 are 15, 50, and 8 pCi/l, respectively.

4.2.1.6 ALLUVIAL GROUND-WATER QUALITY ADJACENT TO LANDFILL

Major Ion Chemistry

Well 59-87 is located at the western extent of the landfill. The well penetrates the intervening clay of the leachate/ground-water collection system and is completed in both the Rocky Flats Alluvium (below the clay) and fill material (above the clay). Although at the time of sampling, ground water occurred below the clay liner, the possible presence of trash even further west toward the surface water intercept ditch, and the fact that a conduit now exists between the fill and alluvium, makes it difficult to assign this well as upgradient of the landfill. Indeed, it appears the ground water at this location may be impacted by the landfill. Analyte concentrations above the upgradient ranges include calcium (78 mg/l), magnesium (14 mg/l), sodium (32 mg/l), bicarbonate (306 mg/l), chloride (24 mg/l), total dissolved solids (406 mg/l), manganese (2.13 mg/l), nickel (0.20 mg/l), strontium (0.62 mg/l), and zinc (0.58 mg/l). Of these analytes, calcium, bicarbonate, total dissolved solids, strontium, and manganese are most elevated (factor of 2-4 higher) relative to upgradient conditions and appear to best represent indicators of a ground-water quality change at the landfill. Total dissolved solids and manganese exceed the proposed ground-water quality criteria (400 mg/l and 0.05 mg/l, respectively). However, manganese concentrations in upgradient ground water also exceed the ground-water quality criteria.

Well 63-87 is located at the north-central edge of the landfill and is within the landfill. Ground-water quality at this location is similar to that observed at well 59-87. Except for nickel, zinc, and chloride, the same analytes exceed the upgradient concentration ranges. Again, calcium (123 mg/l), bicarbonate (392 mg/l), total dissolved solids (519 mg/l), and strontium (0.69 mg/l) significantly exceed the concentrations in upgradient alluvial ground water. Total dissolved solids exceed the ground-water quality criterion at this location.

At wells 62-87, 61-87, and 60-87, each located progressively further north and outside the landfill, ground water appears to represent upgradient conditions. Only sulfate in wells 60-87 (57 mg/l) and 61-87 (59 mg/l) exceeded the upper limit of the upgradient range (49 mg/l). This is likely not a significant difference. This information supports the hydrogeologic findings that the hydraulic gradient at this location is into the landfill and that the clay barrier appears to function.

At well 64-87, located at the south-central edge of the landfill and within the landfill, elevated concentrations of calcium (47 mg/l), chloride (20 mg/l), bicarbonate (179 mg/l), total dissolved solids (255 mg/l), copper (0.057 mg/l), manganese (1.20 mg/l), molybdenum (0.35 mg/l), and strontium (0.33 mg/l) occur. However, in this case, only bicarbonate and molybdenum are significantly elevated. The molybdenum exceeds the proposed ground-water quality criterion (0.1 mg/l); however, this is the only occurrence of elevated molybdenum downgradient of or within the landfill. The significance of this finding is unknown at this time.

At wells 65-87 and 66-87, located progressively further south and outside the landfill, ground water contains higher concentrations of salts and trace metals. Analytes exceeding upgradient concentrations at wells 65-87 and 66-87 are calcium (74 and 34 mg/l), sodium (71 and 95 mg/l), magnesium [13 mg/l (65-87 only)], bicarbonate (208 and 127 mg/l), sulfate [153 mg/l (65-87 only)], total dissolved solids (491 and 405 mg/l), manganese [1.05 mg/l (65-87 only)], copper [0.054 mg/l (66-87 only)], nickel [0.186 mg/l (66-87 only)], strontium (0.50 and 0.30 mg/l), vanadium [0.10 mg/l (66-87 only)], and zinc [0.47 mg/l (66-87 only)]. This data supports the hydrogeologic finding that the hydraulic gradient is away from the landfill at this location. Analytes exceeding the proposed ground-water quality criteria are total dissolved solids and manganese.

East of the landfill in the vicinity of the slurry trenches are wells 71-87, 67-87, 68-87 (north slurry wall), and wells 70-87 and 72-87 (south slurry wall). In general, total dissolved solids (range 191-395 mg/l), bicarbonate (range 101-276 mg/l), sulfate (range 67-139 mg/l), and calcium (range 32-89 mg/l) in all these wells exceed the upgradient alluvial ground-water concentrations. Strontium is only elevated in wells 71-87 and 72-87 which are outside the slurry walls (0.42 and 0.60 mg/l, respectively).

Manganese is only elevated in wells 67-87 and 68-87 which straddle the slurry wall (0.67 and 1.61 mg/l, respectively). Ground water at well 68-87 also contains elevated iron (0.95 mg/l). Well 70-87 was dry. Predicted ground-water flow directions do not support a landfill impact on ground-water quality at wells 67-87 and 71-87. At these locations, ground-water flow is from the north and east. This suggests that the observed concentrations of salts, strontium, and manganese may represent natural spatial variations in ground-water quality. On the contrary, ground water is predicted to flow, at times, south from the landfill at well 64-87 toward wells 65-87 and 66-87, which could proceed east toward well 72-87. Regardless, the observed water quality at well 72-87 does not appear unusual relative to the ground water to the north, which is presumably unimpacted. Iron and manganese are the only analytes which exceed the proposed ground-water quality criteria.

4.2.1.7 Downgradient Alluvial Ground-Water Chemistry

Wells 7-86, 40-87, 42-87, 6-86, and 5-86 are located progressively downgradient of the landfill. Well 7-86 is usually dry, and only organic data exist for this well. Well 40-87 is also dry. Analytes exceeding upgradient concentration ranges for wells 42-87, 6-86, and 5-86 are as follows:

Analyte	Concentration (mg/l)		
	Well 42-87	Well 6-86	Well 5-86
Calcium	71	444	32-473
Magnesium	13	180	6.5-292
Sodium	53	301	22-1179
Bicarbonate	259	227	366-459
Sulfate	75	1710	725-4600
Chloride	14	826	150-270
Iron	.40	.007	.0070-.42
Manganese	.56	1.3	.023-.062
Strontium	1.28	5.12	.17-9.5
Nickel	.037	1.40	.04-.19
Total Dissolved Solids	355	4542	3517-7363

The analyte concentrations observed at well 42-87 may indicate an impact from the landfill; however, as discussed in the previous section, the observed concentrations may be due to natural variations in ground-water chemistry. Iron and manganese exceed the ground-water quality criteria. Iron occurs at high concentrations at well 68-87 but not within landfill (wells 63-87 and 64-87). The limited data makes it difficult to draw conclusions with respect to iron as a contaminant of the landfill. As previously mentioned, the manganese concentration also exceeds the ground-water quality criterion in upgradient ground water and ground water to the north.

The concentrations of analytes at wells 6-86 and 5-86 do not indicate a release from the landfill. These high levels of contamination are not seen within the landfill ground water or immediately downgradient of the landfill (42-87). The implication is another source of high total dissolved solids water exists downgradient of the landfill. As no SWMUs are known to be located downgradient of the landfill, this source may be due to natural saline mineral dissolution.

4.2.2 Bedrock Ground-Water Flow System

4.2.2.1 Recharge Conditions

Ground-water flow in the Arapahoe Formation occurs within sandstones, siltstones, and claystones. Ground-water recharge to the Arapahoe Formation occurs as infiltration of alluvial ground water.

Seasonal variations in saturated thickness are shown in the hydrographs for wells 8-86, 9-86, and 41-87 (Appendix B). The smallest saturated thickness occur from

June through September. There is a downward gradient between ground water in surficial materials and bedrock. This has been demonstrated previously at the Plant (Hurr, 1976, and Rockwell International, 1986a, 1988a). Table 4-7 presents vertical hydraulic gradients calculated for alluvial/bedrock well pairs 7-86 and 8-86 (bedrock well), 10-86 and 9-86 (bedrock well), and 40-87 and 41-87BR. Calculated vertical gradients range from about 0.2 to 0.5.

4.2.2.2 Ground-Water Flow Directions

Ground-water flow within individual sandstones is from west to east at an average gradient of 0.09 ft/ft based on wells completed in the same sandstones at the 903 Pad and East Trenches Areas (Rockwell International, 1987b) and on regional data (Robson and others, 1981a). None of the existing bedrock wells at the Present Landfill are completed in the same sandstone. Therefore, a site-specific horizontal gradient cannot be calculated for Arapahoe sandstone.

4.2.2.3 Hydraulic Conductivities

Hydraulic conductivity values for Arapahoe sandstones were estimated from drawdown-recovery tests performed in 1986, a slug test performed in 1987, and packer tests performed in 1986 and 1987. Tables 4-8 and 4-9 summarize the results of these tests. Data, analyses, and results of each test are provided in Appendix C.

Hydraulic conductivity values in sandstones from drawdown recovery, slug, and packer tests are in good agreement. The hydraulic conductivities in sandstones vary from 4×10^{-8} cm/s to 3.1×10^{-7} cm/s. This is in the range of the hydraulic conductivity calculated for siltstones,

TABLE 4-7

VERTICAL GRADIENTS

Well	Elevation of Potentiometric Surface	Water Level Difference (ft)	Elevation of Saturated Interval Midpoint	Elevation of Saturated Interval	Separator Thickness (ft)	Downview Vertical Gradient
7-86	5920.76		5920.40-5917.66	5919.21		
		18.89			56.83	0.33
8-86	5901.87		5864.73-5860.02	5862.38		
10-86	5987.93		5991.73-5971.24	5979.59		
		20.09			113.32	0.18
9-86	5967.84		5872.66-5859.88	5866.27		
40-87	5879.39		5884.19-5881.23	5880.31		
		38.44			85.03	0.45
41-87	5840.95		5801.57-5788.99	5795.28		

Potentiometric Surface Values Based on April 11, 1988 measurements

TABLE 4-8

RESULTS OF PACKER TESTS IN ARAPAHOE FORMATION

Well No.	Interval (ft)	Lithology	1st P 1/3 (cm/s)	P 2/3 (cm/s)	2nd P 1/3 (cm/s)	Geometric mean (cm/s)
8-86	33.50 - 43.53	Claystone	6.90×10^{-6}	5.06×10^{-6}	3.10×10^{-6}	4.8×10^{-6}
	43.50 - 53.53	Claystone	Aborted	2.1×10^{-7}	Aborted	2.1×10^{-7}
	53.50 - 63.53	Claystone	1.13×10^{-6}	3.0×10^{-8}	Aborted	1.8×10^{-7}
		Claystone		Geometric mean for 8-86:		5.7×10^{-7}
9-86	87.64 - 97.67	Siltstone	-	1.0×10^{-8}	-	1.0×10^{-8}
	97.87 - 107.70	Siltstone	6.0×10^{-8}	3.0×10^{-8}	Aborted	4.0×10^{-8}
	107.70 - 117.93	Siltstone	-	1.0×10^{-8}	-	1.0×10^{-8}
	121.00 - 131.03	Sandstone	1.9×10^{-7}	4.0×10^{-8}	-	9.0×10^{-8}
	135.00 - 145.03	Sandstone/Siltstone				
		Siltstone		Geometric mean for 9-86:		2.0×10^{-8}
		Sandstone		Geometric mean for 9-86:		9.0×10^{-8}
41-87BR	20.85 - 30.50	Claystone	5.7×10^{-7}	1.71×10^{-6}	9.9×10^{-7}	9.9×10^{-7}
	32.50 - 42.15	Sandstone	3.5×10^{-7}	1.0×10^{-7}	2.0×10^{-8}	9.0×10^{-8}
	41.55 - 51.20	Sandstone	9.0×10^{-7}	2.46×10^{-6}	1.75×10^{-6}	1.6×10^{-6}
	53.05 - 62.70	Claystone	2.0×10^{-7}	3.9×10^{-7}	1.0×10^{-7}	2.0×10^{-7}
	62.70 - 72.35	Sandstone	4.2×10^{-7}	6.6×10^{-7}	1.70×10^{-7}	3.6×10^{-7}
	73.35 - 82.00	Claystone	9.1×10^{-7}	2.58×10^{-6}	-	1.5×10^{-6}
	82.00 - 91.65	Sandstone	5.7×10^{-7}	5.0×10^{-8}	-	1.7×10^{-7}
		Claystone		Geometric mean for 41-87BR:		6.7×10^{-7}
		Sandstone		Geometric mean for 41-87BR:		6.7×10^{-7}

TABLE 4-9

RESULTS OF HYDRAULIC TESTS IN BEDROCK

Well No.	Lithology	Drawdown Recovery Test (cm/s)	Slug Test (cm/s)	Packer Test (cm/s)
8-86	Claystone	-	-	5.7×10^{-7}
	Sandstone	7×10^{-8}		
9-86	Siltstone	-	-	2.0×10^{-8}
	Sandstone	4×10^{-8}		9.0×10^{-8}
41-87BR	Claystone	-	-	6.7×10^{-7}
	Sandstone	-	2.78×10^{-8}	3.1×10^{-7}

2×10^{-8} cm/s, and actually less than the range of the hydraulic conductivity for the claystone, 5.7×10^{-7} to 6.7×10^{-7} cm/s.

This very low hydraulic conductivity in the sandstones may explain why the downward gradient from the surficial flow system to the bedrock flow system in the landfill area is not greater than 0.2 to 0.5 ft/ft. This low hydraulic conductivity impairs the ability of the sandstones underlying the landfill area to discharge downdip.

4.2.2.4 Bedrock Ground-Water Quality

Three bedrock monitor wells were installed to monitor bedrock ground-water quality. Well 9-86 is located immediately west of the landfill; 8-86 is located immediately east of the landfill; and 41-87BR is downgradient of the landfill embankment in an unnamed tributary of North Walnut Creek. Table 4-10 summarizes the availability of bedrock ground-water quality data used in this report.

4.2.2.5 Upgradient Bedrock Ground-Water Chemistry

Major Ions

Upgradient bedrock ground-water chemistry is similar to upgradient alluvial ground-water chemistry except for some of the major ions (Table 4-11). Bedrock ground water has higher sodium, bicarbonate, and total dissolved solids relative to alluvial ground water. The ground-water protection criteria for major ions is not exceeded in upgradient bedrock ground water.

Table 4-10

GROUND WATER SAMPLE INFORMATION

LANDFILL BEDROCK WELLS

	SAMPLE INFORMATION			FIELD PARAMETERS			LABORATORY BATCH NUMBERS					
WELL NUMBER	NUMBER	DATE	TYPE	pH	CONDUCT (umho/cm)	TEMP (deg C)	VOLATILE ORGANICS	SEMI-VOL ORGANICS	PESTICIDES AND PCB'S	METALS	INORGANICS	RADIO-CHEMISTRY
0886	6088611860	11/13/86	Routine	11.35	2600	9.5	8611-027-023	No Sample	No Sample	8611-027-024	8611-027-025	1000-000-240
0886	8-86-04-13-87	04/13/87	Routine				0187-881-053	No Sample	No Sample	0187-881-053	0187-881-054	0187-881-054
0886	8-86-06-11-87	06/11/87	Routine	10.20	569	13.0	0287-881-044	No Sample	No Sample	0287-881-044	0287-881-065	0287-881-044
0886	8-86-08-12-87	08/12/87	Routine	9.80	515	15.0	0387-881-078	No Sample	No Sample	0387-881-086	0387-881-082	Insufficient Sample
0886	8-86-12-16-87	12/16/87	Routine	10.50	540	9.6	0487-881-068	No Sample	No Sample	0487-881-056	0487-881-054	0487-881-058
0886	08-86-02-04-88	02/04/88	Routine	9.30	437	9.7	0188-881-019	No Sample	No Sample	0188-881-019	0188-881-019	0188-881-019
0986	6098610860	10/31/86	Routine	8.20	410	[illegible]	8611-004-006	No Sample	No Sample	8611-004-007	8611-004-008	1000-000-215
0986	9-86-05-14-87	05/14/87	Routine	7.40	398	14.0	0187-881-099	No Sample	No Sample	0187-881-099	0187-881-102	0187-881-104
0986	9-86-06-15-87	06/15/87	Routine	7.90	396	14.5	0287-881-046	No Sample	No Sample	0287-881-046	0287-881-049	0287-881-046
0986	9-86-08-12-87	08/12/87	Routine	8.00	395	17.2	0387-881-077	No Sample	No Sample	0387-881-084	0387-881-083	0387-881-060
0986	9-86-01-18-88	01/18/88	Routine	7.60	548	[illegible]	0487-881-102	No Sample	No Sample	0487-881-124	0487-881-083	0487-881-083
0986	09-86-02-04-88	02/04/88	Routine	8.40	400	[illegible]	0188-881-018	No Sample	No Sample	0188-881-018	0188-881-018	0188-881-018
4187	41-87-09-21-87	09/21/87	Routine				0687-881-010	No Sample	No Sample		0687-881-010	
4187	41-87-09-21-87	09/21/87	Routine				8709-078-0150	No Sample	No Sample	Insufficient Sample	Insufficient Sample	Insufficient Sample
4187	41-87-12-17-87	12/17/87	Routine	6.80	2940	[illegible]	0487-881-071	No Sample	No Sample	0487-881-060		0487-881-057
4187	41-87-02-03-88	02/03/88	Routine	7.70	3060	10.1	0188-881-016	No Sample	No Sample	0188-881-016	0188-881-016	0188-881-016

Metals

Metal concentrations in upgradient bedrock ground water are similar to upgradient alluvial ground water. However, unlike alluvial ground water, manganese concentrations do not exceed the proposed ground-water protection standard.

Radionuclides

As with upgradient alluvial ground water, gross alpha and gross beta exceed the proposed ground-water quality criteria in upgradient bedrock ground water. Concentrations for gross alpha and gross beta are as high as 160(100) and 220(60) pCi/l, respectively, while the standards are 15 and 50 pCi/l, respectively.

Table 4

Groundwater Volatile Organic Results for Landfill

Bedrock Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Chloro methane	Bromo methane	Vinyl Chloride	Chloro ethane	Methylene Chloride	Acetone	Carbon Disulfide	1,1-Dichloro ethene	1,1-Dichloro ethane	Trans-1,2-Dichloro ethene
Landfill Bedrock Wells Upgradient														
0986	G098610860	10/31/86		ug/l	10 U	10 U	10 U	10 U	5 U	2 JB	5 U	5 U	5 U	5 U
0986	9-86-05-14-87	05/14/87	1	ug/l	NR	NR	NR	NR	NR	NR	NR	4 U	NR	4 U
0986	9-86-06-15-87	06/15/87	2	ug/l	NR	NR	NR	NR	NR	NR	NR	4 U	NR	4 U
0986	9-86-08-12-87	08/12/87	3	ug/l	NR	NR	NR	NR	NR	NR	NR	5 U	NR	5 U
0986	9-86-01-18-88	01/18/88	4	ug/l	10 U	10 U	10 U	10 U	6	10 U	5 U	5 U	5 U	5 U
0986	09-86-02-04-88	02/04/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
Landfill Bedrock Wells Downgradient														
4187	41-87-09-21-87	09/21/87	3	ug/l	NR	NR	NR	NR	NR	NR	NR	5 U	NR	5 U
4187	41-87-09-21-87	09/21/87	3	ug/l	10 U	10 U	10 U	10 U	5 U	6 JB	5 U	5 U	5 U	5 U
4187	41-87-12-17-87	12/17/87	4	ug/l	10 U	10 U	10 U	10 U	10	10 U	5 U	5 U	5 U	5 U
4187	41-87-02-03-88	02/03/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
0886	G0886111860	11/13/86		ug/l	10 U	10 U	10 U	10 U	5 U	84	5 U	5 U	5 U	5 U
0886	8-86-04-13-87	04/13/87	1	ug/l	NR	NR	NR	NR	NR	NR	NR	4 U	NR	4 U
0886	8-86-06-11-87	06/11/87	2	ug/l	NR	NR	NR	NR	NR	NR	NR	4 U	NR	4 U
0886	8-86-08-12-87	08/12/87	3	ug/l	NR	NR	NR	NR	NR	NR	NR	5 U	NR	5 U
0886	8-86-12-16-87	12/16/87	4	ug/l	10 U	10 U	10 U	10 U	12	4 J	5 U	5 U	5 U	5 U
0886	08-86-02-04-88	02/04/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-11 (,

Groundwater Volatile Organic Results for Landfill

Bedrock Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Chloroform	1,2-Dichloro ethane	2-Butanone	1,1,1 Trichloro ethane	Carbon Tetra chloride	Vinyl Acetate	Bromo dichloro methane	1,2-Dichloro propane	Trans-1,3-Dichloro propene	Trichloro ethene
Landfill Bedrock Wells Upgradient														
0986	G0986108E0	10/31/86		ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
0986	9-86-05-14-87	05/14/87	1	ug/l	4 U	4 U	NR	4 U	4 U	NR	NR	NR	NR	4 U
0986	9-86-06-15-87	06/15/87	2	ug/l	4 U	4 U	NR	4 U	4 U	NR	NR	NR	NR	4 U
0986	9-86-08-12-87	08/12/87	3	ug/l	5 U	5 U	NR	5 U	5 U	NR	NR	NR	NR	5 U
0986	9-86-01-18-88	01/18/88	4	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
0986	09-86-02-04-88	02/04/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
Landfill Bedrock Wells Downgradient														
4187	41-87-09-21-87	09/21/87	3	ug/l	5 U	5 U	NR	5 U	5 U	NR	NR	NR	NR	5 U
4187	41-87-09-21-87	09/21/87	3	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
4187	41-87-12-17-87	12/17/87	4	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
4187	41-87-02-03-88	02/03/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
0886	G0886118E0	11/13/86		ug/l	5 U	5 U	12 B	5 U	5 U	10 U	5 U	5 U	5 U	5 U
0886	8-86-04-13-87	04/13/87	1	ug/l	4 U	4 U	NR	4 U	4 U	NR	NR	NR	NR	4 U
0886	8-86-06-11-87	06/11/87	2	ug/l	4 U	4 U	NR	4 U	4 U	NR	NR	NR	NR	4 U
0886	8-86-08-12-87	08/12/87	3	ug/l	5 U	5 U	NR	5 U	5 U	NR	NR	NR	NR	5 U
0886	8-86-12-16-87	12/16/87	4	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
0886	08-86-02-04-88	02/04/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-11 d.)

Groundwater Volatile Organic Results for Landfill

Bedrock Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Dibromo chloro methane	1,1,2-Trichloro ethane	Benzene	cis-1,3 Dichloro propene	2-Chloro ethylvinyl ether	Bromoform	4-Methyl-2-pentanone	2-Hexanone	Tetrachloro ethene	1,1,2,2 Tetrachloro ethane
Landfill Bedrock Wells Upgradient														
0986	G0986108&0	10/31/86		ug/l	5 U	5 U	5 U	5 U	10 U	5 U	10 U	10 U	5 U	5 U
0986	9-86-05-14-87	05/14/87	1	ug/l	NR	4 U	NR	NR	NR	NR	NR	NR	4 U	NR
0986	9-86-06-15-87	06/15/87	2	ug/l	NR	4 U	NR	NR	NR	NR	NR	NR	4 U	NR
0986	9-86-08-12-87	08/12/87	3	ug/l	NR	5 U	NR	NR	NR	NR	NR	NR	5 U	NR
0986	9-86-01-18-88	01/18/88	4	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
0986	09-86-02-04-88	02/04/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
Landfill Bedrock Wells Downgradient														
4187	41-87-09-21-87	09/21/87	3	ug/l	NR	5 U	NR	NR	NR	NR	NR	NR	5 U	NR
4187	41-87-09-21-87	09/21/87	3	ug/l	5 U	5 U	5 U	5 U	10 U	5 U	10 U	10 U	5 U	5 U
4187	41-87-12-17-87	12/17/87	4	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
4187	41-87-02-03-88	02/03/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
0886	G0886118&0	11/13/86		ug/l	5 U	5 U	5 U	5 U	10 U	5 U	10 U	10 U	5 U	5 U
0886	8-86-04-13-87	04/13/87	1	ug/l	NR	4 U	NR	NR	NR	NR	NR	NR	4 U	NR
0886	8-86-06-11-87	06/11/87	2	ug/l	NR	4 U	NR	NR	NR	NR	NR	NR	4 U	NR
0886	8-86-08-12-87	08/12/87	3	ug/l	NR	5 U	NR	NR	NR	NR	NR	NR	5 U	NR
0886	8-86-12-16-87	12/16/87	4	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
0886	08-86-02-04-88	02/04/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U

Notes: NR - Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-11 .)

Groundwater Volatile Or ..ic Results for Landfill

Bedrock Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Toluene	Chloro benzene	Ethyl benzene	Styrene	Total Xylenes
Landfill Bedrock Wells Upgradient									
0986	C098610860	10/31/86		ug/l	5 U	5 U	5 U	5 U	5 U
0986	9-86-05-14-87	05/14/87	1	ug/l	NR	NR	NR	NR	NR
0986	9-86-06-15-87	06/15/87	2	ug/l	NR	NR	NR	NR	NR
0986	9-86-08-12-87	08/12/87	3	ug/l	NR	NR	NR	NR	NR
0986	9-86-01-18-88	01/18/88	4	ug/l	5 U	5 U	5 U	5 U	5 U
0986	09-86-02-04-88	02/04/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
Landfill Bedrock Wells Downgradient									
4187	41-87-09-21-87	09/21/87	3	ug/l	NR	NR	NR	NR	NR
4187	41-87-09-21-87	09/21/87	3	ug/l	5 U	5 U	5 U	5 U	5 U
4187	41-87-12-17-87	12/17/87	4	ug/l	5 U	5 U	5 U	5 U	5 U
4187	41-87-02-03-88	02/03/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
0886	G0886111860	11/13/86		ug/l	5 U	5 U	5 U	5 U	5 U
0886	8-86-04-13-87	04/13/87	1	ug/l	NR	NR	NR	NR	NR
0886	8-86-06-11-87	06/11/87	2	ug/l	NR	NR	NR	NR	NR
0886	8-86-08-12-87	08/12/87	3	ug/l	NR	NR	NR	NR	NR
0886	8-86-12-16-87	12/16/87	4	ug/l	5 U	5 U	5 U	5 U	5 U
0886	08-86-02-04-88	02/04/88	1	ug/l	5 U	5 U	5 U	5 U	5 U

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-11 d.)

Groundwater Ra. iemistry Results

for Regulated Units at Rocky Flats Plant

Well Number	Field Sample Number	Date Sampled	Qtr.	Gross Alpha	Gross Beta	Uranium 233, 234	Uranium 235	Uranium 238	Strontium 89, 90	Plutonium 239, 240
Landfill Bedrock Wells Upgradient										
0986	G0986108б0	10/31/86		160 +/- 100 pci/l	220 +/- 60 pci/l	0.04 +/- 0.25 pci/l	NR	0.18 +/- 0.35 pci/l	NR	0.39 +/- 0.79 pci/l
0986	9-86-05-14-87	05/14/87	1	5 +/- 0 pc/l	0 +/- 9 pc/l	1.8 +/- 1.4 pc/l	.85 +/- .74 pc/l	.28 +/- .97 pc/l	1.03 pc/l	0.6 +/- 1.2 pc/l
0986	9-86-06-15-87	06/15/87	2	45 +/- 21 pci/l	67 +/- 6 pci/l	2.2 +/- 1.0 pci/l	0.0 +/- 0.26 pci/l	0.32 +/- 0.5 pci/l	<1.0 pci/l	0.0 +/- 0.65 pci/l
0986	9-86-08-12-87	08/12/87	3	12 +/- 20 pci/l	12 +/- 39 pci/l	1.9 +/- 1.5 pci/l	-0.2 +/- 0.2 pci/l	5.3 +/- 2.0 pci/l	<1.0 pci/l	-0.3 +/- 1.4 pci/l
0986	9-86-01-18-88	01/18/88	4	2 +/- 5 pci/l	-1 +/- 11 pci/l	3.0 +/- 0.5 pci/l	.06 +/- .10 pci/l	.98 +/- .28 pci/l	<1.0 pci/l	0.00 +/- .14 pci/l
0986	09-86-02-04-88	02/04/88	1	1 +/- 5 pci/l	-4 +/- 11 pci/l	1.1 +/- 0.24 pci/l	0.09 +/- 0.07 pci/l	0.24 +/- 0.12 pci/l	NR	0.0 +/- 0.58 pci/l
Landfill Bedrock Wells Downgradient										
4187	41-87-09-21-87	09/21/87	3	NA	NA	NA	NA	NA	NA	NA
4187	41-87-09-21-87	09/21/87	3	NA	NA	NA	NA	NA	NA	NA
4187	41-87-12-17-87	12/17/87	4	109 +/- 22 pci/l	123 +/- 15 pci/l	NR	NR	NR	<1.0 pci/l	0.60 +/- .14 pci/l
4187	41-87-02-03-88	02/03/88	1	3 +/- 6 pci/l	-4 +/- 13 pci/l	0.26 +/- 0.18 pci/l	0.01 +/- 0.06 pci/l	0.15 +/- 0.17 pci/l	NR	0.0 +/- 2.0 pci/l
0886	G08861186O	11/13/86		16 +/- 41 pci/l	61 +/- 30 pci/l	-0.09 +/- 0.44 pci/l	NR	-0.3 +/- 1.8 pci/l	NR	-1.0 +/- 1.6 pci/l
0886	8-86-04-13-87	04/13/87	1	8 +/- 4 pc/l	21 +/- 12 pc/l	0.0 +/- .45 pc/l	0.0 +/- .41 pc/l	0.0 +/- .75 pc/l	<0.6 pc/l	.21 +/- .85 pc/l
0886	8-86-06-11-87	06/11/87	2	20 +/- 10 pci/l	51 +/- 45 pci/l	0.18 +/- 0.61 pci/l	0.26 +/- 0.45 pci/l	2.3 +/- 5.4 pci/l	1.3 pci/l	0.05 +/- 0.62 pci/l
0886	8-86-08-12-87	08/12/87	3	NA	NA	NA	NA	NA	NA	NA
0886	8-86-12-16-87	12/16/87	4	4 +/- 17 pci/l	4 +/- 11 pci/l	.98 +/- .21 pci/l	.03 +/- .04 pci/l	.45 +/- .14 pci/l	<1.0 pci/l	0.00 +/- .16 pci/l
0886	08-86-02-04-88	02/04/88	1	3 +/- 5 pci/l	-7 +/- 12 pci/l	2.9 +/- 0.63 pci/l	0.08 +/- 0.12 pci/l	0.90 +/- 0.30 pci/l	NR	0.0 +/- 0.31 pci/l

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis

Table 4-1 ... d.)

Groundwater Ra... ...hemistry Results

for Regulated Units at Rocky Flats Plant

Well Number	Field Sample Number	Date Sampled	Qtr.	Americium 241	Cesium 137	Tritium
Landfill Bedrock Wells Upgradient						
0986	G098610860	10/31/86		-0.17 +/- 0.34 pci/l	NR	0.05 +/- 0.21 pci/ml
0986	9-86-05-14-87	05/14/87	1	0.0 +/- 1.2 pc/l	NR	<110 pc/l
0986	9-86-06-15-87	06/15/87	2	0.0 +/- 1.2 pci/l	NR	<110 pci/l
0986	9-86-08-12-87	08/12/87	3	.19 +/- .29 pci/l	NR	<492 pci/l
0986	9-86-01-18-88	01/18/88	4	0.00 +/- .12 pci/l	NR	<220 pci/l
0986	09-86-02-04-88	02/04/88	1	NR	NR	<210 pci/l
Landfill Bedrock Wells Downgradient						
4187	41-87-09-21-87	09/21/87	3	NA	NA	NA
4187	41-87-09-21-87	09/21/87	3	NA	NA	NA
4187	41-87-12-17-87	12/17/87	4	0.00 +/- .32 pci/l	NR	<210 pci/l
4187	41-87-02-03-88	02/03/88	1	NR	NR	<210 pci/l
0886	G0886116c0	11/13/86		-0.44 +/- 0.79 pci/l	NR	0.01 +/- 0.2? pci/ml
0886	8-86-04-13-87	04/13/87	1	0.0 +/- 1.2 pc/l	NR	<110 pc/l
0886	8-86-06-11-87	06/11/87	2	0.0 +/- 1.2 pci/l	NR	<110 pci/l
0886	8-86-08-12-87	08/12/87	3	NA	NA	NA
0886	8-86-12-16-87	12/16/87	4	.02 +/- .10 pci/l	NR	<210 pci/l
0886	08-86-02-04-88	02/04/88	1	NR	NR	<210 pci/l

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis

Table 4-11 (...)

Groundwater Inorgan... Results for Landfill

Bedrock Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	CO3=	HCO3-	Chloride	Sulfate	pH	Fluoride	Nitrate-Nitrite-Nitrogen
Landfill Bedrock Wells Upgradient										
0986	G0986108G0	10/31/86		5 U mg/l	220 mg/l	11 mg/l	15 mg/l	NR	NR	NR
0986	9-86-05-14-87	05/14/87	1	NR	172 mg/l	13.2 mg/l	10.0 mg/l	NR	NR	0.20 U mg/l
0986	9-86-06-15-87	06/15/87	2	NR	192 mg/l	10.5 mg/l	7.80 mg/l	NR	NR	0.20 U mg/l
0986	9-86-08-12-87	08/12/87	3	NR	187 mg/l	10.5 mg/l	8.5 mg/l	NR	NR	0.20 U mg/l
0986	9-86-01-18-88	01/18/88	4	NR	201 mg/l	11.23 mg/l	10.3 mg/l	NR	NR	0.02 U mg/l
0986	09-86-02-04-88	02/04/88	1	NR	205 mg/l	8.44 mg/l	151 mg/l	NR	NR	0.02 U mg/l
Landfill Bedrock Wells Downgradient										
4187	41-87-09-21-87	09/21/87	3	NF	NF	NF	NF	NF	NF	NF
4187	41-87-09-21-87	09/21/87	3	NA	NA	NA	NA	NA	NA	NA
4187	41-87-12-17-87	12/17/87	4	NA	NA	NA	NA	NA	NA	NA
4187	41-87-02-03-88	02/03/88	1	NR	114 mg/l	928 mg/l	44.3 mg/l	NR	NR	0.02 U mg/l
0886	G0886118G0	11/13/86		450 mg/l	3 U mg/l	12 mg/l	101 mg/l	NR	NR	NR
0886	8-86-04-13-87	04/13/87	1	NR	21.4 mg/l	872 mg/l	200 mg/l	NR	NR	2.10 mg/l
0886	8-86-06-11-87	06/11/87	2	12.4 mg/l	36.6 mg/l	9.50 mg/l	225 mg/l	NR	NR	0.20 U mg/l
0886	8-86-08-12-87	08/12/87	3	NR	61.5 mg/l	9.7 mg/l	178 mg/l	NR	NR	NR
0886	8-86-12-16-87	12/16/87	4	NR	57.7 mg/l	7.93 mg/l	151 mg/l	NR	NR	1.47 mg/l
0886	08-86-02-04-88	02/04/88	1	NR	80.2 mg/l	8.19 mg/l	125 mg/l	NR	NR	0.34 mg/l

Notes: NR : *Analyte not reported*
NA : Insufficient water in well for analysis
U : *Analyzed but not detected*
J : Present below detection limit
B : Present in laboratory blank

Table 4-11 .)

Groundwater Inorga. .esults for Landfill

Bedrock Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Sulfide	Phosphate	Cyanide, Total	Hexavalent Chromium (Cr+6)	Total Dissolved Solids	Suspended Solids	% Solids
Landfill Bedrock Wells Upgradient										
0986	G0986108G0	10/31/86		NR	NR	0.01 U mg/l	NR	350 mg/l	NR	NR
0986	9-86-05-14-87	05/14/87	1	NR	NR	1.0 U mg/l	NR	217 mg/l	NR	NR
0986	9-86-06-15-87	06/15/87	2	NR	NR	1.0 U mg/l	NR	255 mg/l	NR	NR
0986	9-86-08-12-87	08/12/87	3	NR	NR	1 U mg/l	NR	220 mg/l	NR	NR
0986	9-86-01-18-88	01/18/88	4	NR	NR	NR	NR	224 mg/l	NR	NR
0986	09-86-02-04-88	02/04/88	1	NR	NR	NR	NR	238 mg/l	NR	NR
Landfill Bedrock Wells Downgradient										
4187	41-87-09-21-87	09/21/87	3	NF	NF	NF	NF	NF	NF	NF
4187	41-87-09-21-87	09/21/87	3	NA	NA	NA	NA	NA	NA	NA
4187	41-87-12-17-87	12/17/87	4	NA	NA	NA	NA	NA	NA	NA
4187	41-87-02-03-88	02/03/88	1	NR	NR	NR	NR	1880 mg/l	NR	NR
0886	G0886118G0	11/13/86		NR	NR	0.005 U mg/l	NR	911 mg/l	NR	NR
0886	8-86-04-13-87	04/13/87	1	NR	NR	1.0 U mg/l	NR	402 mg/l	NR	NR
0886	8-86-06-11-87	06/11/87	2	NR	NR	1.0 U mg/l	NR	380 mg/l	NR	NR
0886	8-86-08-12-87	08/12/87	3	NR	NR	1 U mg/l	NR	358 mg/l	NR	NR
0886	8-86-12-16-87	12/16/87	4	NR	NR	NR	NR	330 mg/l	NR	NR
0886	08-86-02-04-88	02/04/88	1	NR	NR	NR	NR	307 mg/l	NR	NR

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-11 .)

Groundwater Metal. esults for Landfill

Bedrock Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Silver (Ag), total	Aluminum (Al), total	Arsenic (As), total	Barium (Ba), total	Beryllium (Be), total	Calcium (Ca), total	Cadmium (Cd), total	Colbalt (Co), total	Chromium (Cr), total	Cesium (Cs), total
Landfill Bedrock Wells Upgradient														
0986	G09861086O	10/31/86		mg/l	0.010 U	0.100 U	0.010 U	0.160	0.005 U	21.1	0.005 U	0.025 U	0.010 U	0.150 U
0986	9-86-05-14-87	05/14/87	1	mg/l	0.0076 U	0.0421	0.01 U	0.0907	0.005 U	25.8270	0.005 U	0.0220 U	0.0100 U	.. 0.2 U
0986	9 86-06-15-87	06/15/87	2	mg/l	0.0076 U	0.0290 U	0.01 U	0.0279	0.005 U	25.6395	0.005 U	0.0220 U	0.0100 U	0.2 U
0986	9 86-08-12-87	08/12/87	3	mg/l	0.0076 U	0.0487	0.004 J	0.1303	0.005 U	22.8456	0.0004 J	0.0220 U	0.0178	0.02 U
0986	9-86-01-18-88	01/18/88	4	mg/l	0.0076 U	0.0551	0.015	0.1323	0.005 U	24.6412	0.001 U	0.0220 U	0.0100 U	0.02 U
0986	09-86-02-04-88	02/04/88	1	mg/l	0.0076 U	0.0290 U	0.005 U	0.1067	0.005 U	21.8304	0.001 U	0.0220 U	0.0137	0.02 U
Landfill Bedrock Wells Downgradient														
4187	41-87-09-21-87	09/21/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4187	41-87-09-21-87	09/21/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4187	41-87-12-17-87	12/17/87	4	mg/l	0.0076 U	0.0699	0.002 J	0.1813	0.005 U	96.1860	0.001 U	0.0220 U	0.0100 U	0.02 U
4187	41-87-02-03-88	02/03/88	1	mg/l	0.0076 U	0.0350	0.003 J	0.2899	0.005 U	96.0820	0.001	0.0220 U	0.0100 U	0.02 U
0886	G08861186O	11/13/86		mg/l	0.009 U	0.380	0.010 U	0.156	0.005 U	91.5	0.005 U	0.025 U	0.010 U	0.150 U
0886	8-86-04-13-87	04/13/87	1	mg/l	0.0076 U	0.1209	0.01 U	0.0338	0.005 U	32.2310	0.005 U	0.0220 U	0.0100 U	0.2 U
0886	8-86-06-11-87	06/11/87	2	mg/l	0.0076 U	0.1254	0.01 U	0.0135	0.005 U	26.0747	0.005 U	0.0220 U	0.0100 U	0.2 U
0886	8-86-08-12-87	08/12/87	3	mg/l	0.0076 U	0.0730	0.01	0.0478	0.005 U	25.6007	0.001 U	0.0220 U	0.0103	0.02 U
0886	8-86-12-16-87	12/16/87	4	mg/l	0.0076 U	0.0722	0.007	0.0268	0.005 U	19.3936	0.001 U	0.0220 U	0.0100 U	0.02 U
0886	08-86-02-04-88	02/04/88	1	mg/l	0.0076 U	0.0416	0.005 U	0.0164	0.005 U	16.0180	0.001 U	0.0220 U	0.0100 U	0.02 U

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-1 [illegible]d.)

Groundwater Metals Results for Landfill

Bedrock Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Copper (Cu), total	Iron (Fe), total	Mercury (Hg), total	Potassium (K), total	Lithium (Li), total	Magnesium (Mg), total	Manganese (Mn), total	Molybdenum (Mo), total	Sodium (Na), total	Nickel (Ni), total
Landfill Bedrock Wells Upgradient														
0986	G0986108&0	10/31/86		mg/l	0.020 U	0.075 U	0.0002 U	3.62	NR	5.25	0.028	0.100 U	60.7	0.020 U
0986	9-86-05-14-87	05/14/87	1	mg/l	0.0068	0.0207	0.0002 U	5.0 U	NR	6.1611	0.0127	0.0220 U	61.5676	0.0370 U
0986	9-86-06-15-87	06/15/87	2	mg/l	0.0063 U	0.0131	0.0002 U	5.0 U	NR	5.5015	0.0312	0.0220 U	60.6963	0.0370 U
0986	9-86-08-12-87	08/12/87	3	mg/l	0.0071	0.2267	0.0002 U	3.9	NR	5.1208	0.0212	0.0290	72.1430	0.0370 U
0986	9-86-01-18-88	01/18/88	4	mg/l	0.0257	0.0519	0.0002 U	3.6	0.1 U	5.6543	0.0338	0.0220 U	60.9950	0.0370 U
0986	09-86-02-04-88	02/04/88	1	mg/l	0.0063 U	0.0825	0.0002	3.5	0.1 U	5.4654	0.0236	0.0220 U	57.6813	0.0370 U
Landfill Bedrock Wells Downgradient														
4187	41-87-09-21-87	09/21/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4187	41-87-09-21-87	09/21/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4187	41-87-12-17-87	12/17/87	4	mg/l	0.0246	0.0532	0.0002 U	9.9	0.10	24.1295	0.0653	0.0456	4447.3764	0.0370 U
4187	41-87-02-03-88	02/03/88	1	mg/l	0.0063 U	0.0372	0.0002 U	8.6	0.13	25.5941	0.0821	0.0343	442.8450	0.0370 U
0886	G0886118&0	11/13/86		mg/l	0.020 U	0.094	0.0002 U	41.1	NR	1 U	0.016	0.133	177	0.020 U
0886	8-86-04-13-87	04/13/87	1	mg/l	0.0063 U	0.0069 U	0.0002 U	10.0	NR	1.2284	0.0051 U	0.1247	101.4100	0.0370 U
0886	8-86-06-11-87	06/11/87	2	mg/l	0.0079	0.0447	0.0002 U	7.6	NR	0.3173	0.0051 U	0.1241	89.6748	0.0370 U
0886	8-86-08-12-87	08/12/87	3	mg/l	0.0074	0.0294	0.0002 U	5.9	NR	1.1104	0.0051 U	0.1332	88.5283	0.0370 U
0886	8-86-12-16-87	12/16/87	4	mg/l	0.0330	0.0384	0.0002 U	6.2	0.1 U	1.2793	0.0051 U	0.0732	78.2412	0.0370 U
0886	08-86-02-04-88	02/04/88	1	mg/l	0.0092	0.0320	0.0002 U	4.9	0.06 J	1.4480	0.0051 U	0.0410	71.9646	0.0370 U

Notes:
NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-11 [illegible].)

Groundwater Metals Results for Landfill

Bedrock Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Lead (Pb), total	Antimony (Sb), total	Selenium (Se), total	Strontium (Sr), total	Thallium (Tl), total	Vanadium (V), total	Zinc (Zn), total
Landfill Bedrock Wells Upgradient											
0986	G0986108б0	10/31/86		mg/l	0.025	0.060 U	0.005 U	0.175	0.010 U	0.025 U	0.020 U
0986	9-86-05-14-87	05/14/87	1	mg/l	0.005 U	0.0600 U	0.0050 U	0.2726	0.01 U	0.0240 U	0.02 U
0986	9-86-06-15-87	06/15/87	2	mg/l	0.015	0.06 U	0.005 U	0.2263	0.01 U	0.0295	0.0200 U
0986	9-86-08-12-87	08/12/87	3	mg/l	0.001 J	0.02 U	0.004	0.2387	0.01 U	0.0240 U	0.2433
0986	9-86-01-18-88	01/18/88	4	mg/l	0.002 J	0.02 U	0.002 J	0.2800	0.01 U	0.0240 U	0.0200 U
0986	09-86-02-04-88	02/04/88	1	mg/l	0.005 U	0.02 U	0.005 U	0.2572	0.01 U	0.0240 U	0.0423
Landfill Bedrock Wells Downgradient											
4187	41-87-09-21-87	09/21/87	3		NA	NA	NA	NA	NA	NA	NA
4187	41-87-09-21-87	09/21/87	3		NA	NA	NA	NA	NA	NA	NA
4187	41-87-12-17-87	12/17/87	4	mg/l	0.005 U	0.02 U	0.005	1.3371	0.01 U	0.0240 U	0.0242
4187	41-87-02-03-88	02/03/88	1	mg/l	0.005 U	0.02 U	0.004 J	1.3304	0.01 U	0.0240 U	0.0263
0886	G088611860	11/13/86		mg/l	0.005 U	0.060 U	0.010	1.310	0.010 U	0.025 U	0.029
0886	8-86-04-13-87	04/13/87	1	mg/l	0.005 U	0.0600 U	0.006	0.3843	0.01 U	0.0324	0.02
0886	8-86-06-11-87	06/11/87	2	mg/l	0.008	0.06 U	0.005 U	0.3013	0.01 U	0.0333	0.0200 U
0886	8-86-08-12-87	08/12/87	3	mg/l	0.005 U	0.02 U	0.005 U	0.2818	0.01 U	0.0240 U	0.0200 U
0886	8-86-12-16-87	12/16/87	4	mg/l	0.005 U	0.02 U	0.006	0.2535	0.01 U	0.0240 U	0.0200 U
0886	08-86-02-04-88	02/04/88	1	mg/l	0.005 U	0.02 U	0.005 U	0.1896	0.01 U	0.0240 U	0.0200 U

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

4.2.2.6 DOWNGRADIENT BEDROCK GROUND-WATER CHEMISTRY

Well 8-86, at the west end of the landfill pond, and well 41-87 at the toe of the landfill pond embankment, are the two downgradient bedrock wells. Analyte concentrations in ground water at these wells exceed the upgradient conditions as shown below:

Analyte	Upgradient Range (mg/l)	Concentration Ranges (mg/l) 8-86	41-87
Calcium	21-26	16-91	96
Magnesium	5-6	-*	24-26
Sodium	58-72	72-177	443
Chloride	8-13	8-872	928
Sulfate	8-15	101-225	44
Nitrate	.20	.20-2.1	-
Total Dissolved Solids	217-350	307-911	1880
Aluminum	.0290-.055	.042-.380	.035-.070
Manganese	.013-.034	-	.065-.082
Molybdenum	.10	.04-.13	-
Selenium	.0050	.0050-.010	-
Strontium	.18-.28	.19-1.31	1.33-1.34

* - indicated, upgradient concentration not exceeded

Relative to the ground water at well 9-86 (upgradient), the ground water at wells 8-86 and 41-87 is particularly enriched (more so at 41-87 than 8-86) in calcium, magnesium, sodium, chloride, and strontium. These high concentrations are not observed in alluvial ground water within, adjacent, or immediately downgradient of the landfill. Although it is possible the sandstones in 8-86 and 41-87 subcrop beneath the landfill (Cross Section A-A') and thus are recharged by alluvial ground water in this vicinity, it is likely the quality of the ground water in the sandstones at these wells simply reflects dissolution of minerals within the sandstone and claystone. The higher salt concentration at 41-87 relative to 8-86 could be explained by the somewhat longer contact time and resulting mineral dissolution of water moving from the alluvium to well 41-87. The observed lower concentrations of salts in well 9-86 may be due to lower mineral content within the sandstone and claystone in this vicinity. It is concluded that the apparent "degradation' of bedrock ground water downgradient of the landfill is not related to releases from the landfill.

4.2.2.7 GROUND-WATER QUALITY SUMMARY

Examination of water quality data for upgradient alluvial ground water and alluvial ground water within the landfill, adjacent to and south of the landfill, and immediately downgradient of the landfill, indicates the landfill may be contributing calcium, bicarbonate, and to a lesser extent sodium, sulfate, iron, manganese, and strontium to the ground water. However, ground water to the north of the north slurry wall which is not influenced by the landfill has similar concentrations of these analytes. This implies that even if the landfill contributes these constituents to the ground water, the resulting concentrations are within natural variations for the area. With respect to the public health significance of the water quality directly downgradient of the landfill (42-87), only iron (0.40 mg/l) and manganese (0.57 mg/l) exceed the ground-water quality criteria (0.3 and 0.05 mg/l, respectively). However, manganese also exceeds the criteria (maximum concentration of 0.63 mg/l) in upgradient ground water.

It is concluded that any impacts the landfill has on alluvial ground water do not alter the quality to any significant extent relative to the natural variations in quality observed in the vicinity of the landfill and relative to public health-based water quality criteria. High salt concentrations further down the drainage (wells 6-86 and 5-86) appear to result from another, yet unidentified and presumably natural source.

Bedrock ground-water quality is conjectured to be influenced largely by mineral dissolution within the sandstones and claystone, as the high salt concentrations observed are not seen in alluvial ground water within the landfill.

4.3 PERFORMANCE OF PROPOSED CAP AND LEACHATE SYSTEM

The performance of the proposed cap and leachate system is dependent not only on its design characteristics, but also on the effectiveness of the intercept and slurry trenches in already place.

4.3.1 Effectiveness of the Ground-Water Intercept, Clay Liner and Slurry Trenches

Section 4.2.1.2 of this text discussed the effectiveness of the leachate/ground-water collection system (including the clay liner) and of the slurry trenches. In this section a water balance approach is used to evaluate the effectiveness of the ground-water intercept/clay liner and the slurry trenches in isolating the landfill from the alluvial ground-water flow system. If the intercept/slurry wall does isolate the landfill, rates of recharge from precipitation should approximate rates of discharge into the bedrock and into the landfill pond.

Conclusion

It appears from water balance calculations that the ground-water intercept and slurry trenches are not completely effective in isolating the landfill from the alluvial ground-water flow system.

Estimated recharge rates for the landfill from incident precipitation vary from 24,000 to 152,000 cubic feet per year. The range is a function of precipitation rate and percentage of precipitation estimated to recharge the water table.

Estimated discharge rates for the landfill vary from 187,000 to 392,000 cubic feet per year. Actual discharge rates may be higher because ground-water flow in the alluvial toe of the landfill was not estimated.

Recharge

Table 4-12 lists the annual rainfall at the Rocky Flats Plant for the years 1953 through 1987. The 35-year average annual precipitation is 15.15 inches; the maximum recorded annual precipitation is 24.67 inches in 1969; and the minimum is 7.76 inches in 1954.

A large fraction of this precipitation is lost as runoff and as evapotranspiration. The percentage of annual precipitation that recharges the ground-water system is quite low. Table 4-13 (after Gutentag, et al., 1984) compiles these values for the unconfined High Plains Aquifer in Colorado. With reference to this table, it is estimated that 5 to 10 percent of annual precipitation recharges the ground-water flow system within the landfill.

The volume of ground-water recharge resulting from incident precipitation is the product of the annual precipitation, the percent of resulting recharge (as a fraction), and the landfill area. The landfill area within the ground-water intercept and slurry trenches is approximately 740,000 square feet. Recharge rates for the historical rates of precipitation are listed in Table 4-14.

TABLE 4-12

ANNUAL RAINFALL AT THE ROCKY FLATS PLANT

Year	Rainfall	Year	Rainfall
1953	11.26	1971	14.30
1954	7.76	1972	14.78
1955	14.77	1973	21.55
1956	13.42	1974	13.73
1957	22.67	1975	12.22
1958	18.07	1976	13.51
1959	19.65	1977	8.73
1960	13.72	1978	13.53
1961	16.08	1979	19.14
1962	8.26	1980	12.96
1963	12.23	1981	13.24
1964	8.79	1982	17.95
1965	18.87	1983	21.62
1966	10.24	1984	11.32
1967	22.54	1985	14.23
1968	12.71	1986	15.13
1969	24.67	1987	18.17
1970	18.56		

35-Year Average Annual Rainfall: 15.15 inches (1.26 feet; 38.5 cm)
Maximum Recorded Annual Rainfall: 24.67 inches (1969)
Minimum Recorded Annual Rainfall: 7.76 inches (1954)

Data for years 1953-1976 from DOE, 1980, Table 2.3.6-6.
Data for years 1977-1987 from rainfall measured at Building 774--Rocky Flats.

TABLE 4-13

RECHARGE ESTIMATES FOR THE HIGH PLAINS AQUIFER

State	Recharge		Reference	Remarks
	In inches per year	In percentage of mean annual precipitation		
Colorado	0.80 to 0.95	5	McGovern and Coffin (1963)	Northern High Plains, water-budget method
	0.95	5	McGovern (1964)	Washington County, water-budget method
	0.82	5	Reddell (1967)	Northern High Plains, county averages range from 0.15 (Kiowa) to 1.45 inches per year (Yuma), computer-model analysis
	4.0	23	Longenbaugh and Krishnamurthi (1975)	Washington County, sandy soils, computer-model analysis
	0.59	2	Kapple and others (1977)	Cheyenne and Kiowa Counties, computer-model analysis

TABLE 4-14

EXPECTED RECHARGE (ft^3) TO LANDFILL AREA (inches)

		Annual Precipitation Min	Avg	Max
		7.76	15.15	24.67
Percent of precipitation that recharges ground-water system	5%	276,000	539,000	878,000
	10%	426,000	832,000	1,354,000

Discharge

Ground water within the landfill is discharged by eastward flow into the landfill pond, by seepage into the bedrock, and by possible, intermittent southward flow across the clay liner.

The possibility of intermittent southward flow across the clay liner is discussed in Section 4.2.1.2. There is insufficient documentation on this flow to estimate annual discharge rates.

Ground water discharge to bedrock can be estimated from Darcy's equation:

$$Q = K\ A\ (dh/dL)$$

Where: K = hydraulic conductivity
A = cross sectional area of flow
dh/dL = hydraulic gradient

As discussed in Section 4.2.2.1, there is a downward gradient between ground water in surficial materials and bedrock. Calculated vertical gradients in the landfill area range from 0.2 to 0.5 (See Table 4-6).

The cross sectional flow area for downward flow into bedrock is the surface area of the landfill. This is approximately 740,000 square feet.

Hydraulic conductivities for the bedrock formations are summarized in Table 4-8. Because claystone underlies most of the landfill, a hydraulic conductivity representative of claystone is used. Two hydraulic conductivities for claystone are available: 5.7×10^{-7} cm/s from well 8-86; and 6.7×10^{-7} cm/s from well 41-87BR. The geometric mean of these values is 6.2×10^{-7} cm/s. This is a measurement of the horizontal hydraulic conductivity. Freeze and Cherry (1979) state that in general vertical permeabilities are less than horizontal, but that the ratio of horizontal to vertical hydraulic conductivities is usually less than three.

As shown below, estimate discharge into the bedrock formations vary from 32,000 to 237,000 cubic feet of water per year.

EXPECTED DISCHARGE (ft^3/yr) FROM LANDFILL

Hydraulic Conductivity (cm/s) (ft/ft)	Downward Hydraulic Gradient	
	.2	.5
$6.2x10^{-7}$	95,000	237,000
$2.1x10^{-7}$	32,000	80,000

Discharge from the landfill into the Landfill Pond is composed of two components. Ground-water flow along the thin alluvial toe at the base of the landfill, and surface water flow from seepage at the base of the landfill.

Because there is insufficient data to estimate a hydraulic gradient across the alluvial material at the base of the landfill, this rate of discharge cannot be estimated.

On June 16, 1988 the flow of the seepage was measured with a Baski Cutthroat flume. The measured flow rate was 2.2 gallons per minute. Although this landfill seepage is a recent phenomenon (first noticed in April, 1988), it is assumed this represents a stable discharge rate. Based on this rate, the landfill is discharging 155,000 cubic feet of water per year.

Total discharge of ground water from the landfill is estimated at a range of 187,000 to 392,000 cubic feet of ground water per year. Not included in either of these values is the unknown discharge within the alluvium at the base of the landfill.

4.3.2 Performance of the Proposed Cap

The primary function of the proposed cap will be a reduction in the recharge from incident precipitation. As discussed above, the estimated rate of recharge from incident precipitation ranges from 24,000 to 152,000 cubic feet per year. This will be reduced to the 1,000 cubic feet per year estimated in Section 4.2.8 of the closure plan.

While water levels can be expected to drop with the installation of the proposed cap, some water will remain in the landfill. As concluded in Section 4.3.1, the landfill is probably not hydraulically isolated from the alluvial ground-water flow system; therefore, a component ground-water recharge can be expected. Essential for keeping water levels low in the landfill is the ability to remove ground water from the eastern end.

4.3.3 Performance of the Proposed Leachate Collection System

The proposed leachate collection system is designed to collect leachate at the low end of the landfill at expected rates of less than one gallon per minute (Closure Plan, Section 5.2.4). Currently the seepage at the low of the landfill is discharging at 2.2 gallons per minute. This should be reduced with the installation of the proposed cap.

SECTION 5

SURFACE WATER CHARACTERIZATION

The Present Landfill area is drained by an eastward flowing unnamed tributary to North Walnut Creek. A landfill retention pond, also known as the east pond, is located downstream of the Present Landfill on the unnamed tributary. The pond was designed to receive surface and subsurface flow from the landfill. The unnamed tributary joins North and South Walnut Creek approximately 0.7 miles downstream of the eastern edge of the Plant security area before flowing into Great Western Reservoir approximately one mile east of the confluence.

5.1 SURFACE WATER FLOW--UNNAMED TRIBUTARY TO WALNUT CREEK

During August 1986, as part of the initial Rocky Flats Plant site characterization (Rockwell, 1986a), flow rates were measured in all of the site natural drainages and ditches using either a portable cut-throat flume or the Parshall flumes used for NPDES monitoring. Surface water monitoring stations are shown on Plate 5-1. Flow rates were not measured during 1987 surface water sampling.

Three surface water stations were established on the unnamed tributary of Walnut Creek draining the area near the Present Landfill. These stations are SW-10 (upgradient of the landfill), SW-13 (upstream of the landfill retention pond), SW-14 (immediately downstream of the landfill retention pond), and SW-15 (immediately upstream of the confluence with North Walnut Creek). There was no flow in the tributary at these stations in late August 1986. Flow in the tributary is seasonal and is dependent upon precipitation and ground-water flow. The landfill pond, however, was sampled.

The landfill pond is essentially recharged by ground water and surface runoff from the landfill located upgradient. The potentiometric surface maps (Plates 4-7 and 4-8) indicate flow from the landfill is in an easterly direction toward the landfill retention pond. The potentiometric surface maps also indicate the water table is at or near the retention pond water elevation.

Ground water at the north and south hillsides of the landfill above the pond locally flows toward the pond. Water loss from the retention pond consists of natural evaporation which is enhanced by spraying water through fog nozzles and spray irrigation over the pond and on the hill to the south of the pond. The pond does not directly discharge to the drainage downgradient.

5.2 WATER QUALITY

Surface water quality data collected to date consist of samples collected in August 1986 and September 1987 from the landfill pond (Table 5-1), and historical data (Appendix D). Historical data are discussed in Section 5.3. The 1986 and 1987 samples were analyzed for HSL volatile organics, semi-volatiles, pesticide/PCBs, major ion inorganics, metals, and radionuclides.

Background surface water quality at the Rocky Flats Plant has not been thoroughly characterized; however, for the purpose of characterizing surface water downgradient of the Solar Ponds, the chemistry of the surface water quality is compared to local alluvial groundwater quality and health based water quality

Table 5-1

SURFACE WATER SAMPLE INFORMATION

LANDFILL SURFACE WATER STATIONS

	SAMPLE INFORMATION			FIELD PARAMETERS			LABORATORY BATCH NUMBERS					
STATION NUMBER	NUMBER	DATE	TYPE	pH	CONDUCT (umho/cm)	TEMP (deg C)	VOLATILE ORGANICS	SEMI-VOL ORGANICS	PESTICIDES AND PCB'S	METALS	INORGANICS	RADIO-CHEMISTRY
SW03	SW03088600	08/20/86	Routine	6.80	350	20.0	8608-044-021	8608-064-004	8608-064-004	8608-044-022	8608-044-023	1000-000-369
SW13	DRY	08/11/86										
SW14	DRY	08/12/86										
SW15	DRY	08/12/86										
SWLFP	SWLFP08860	08/14/86	Routine	7.50	830	21.0	8608-029-025	8608-055-005	8608-055-005	8608-029-027	8608-029-028	1000-000-405

criteria. The water quality criteria examined are The Safe Drinking Water Act (SDWA) Maximum Contaminant Levels (MCLs), and the Colorado Department of Health (CDH) in-stream standards for tributaries to Great Western Reservoir. These surface water quality criteria are presented in Table 5-2. Where an MCL and an in-stream standard both exist for an analyte, it is noted that they are equivalent. It is further noted that a discharge to the drainage is necessary for these criteria to be considered enforceable. They are presented here merely to provide perspective for the water quality observed at the Rocky Flats Plant.

HSL volatile organics, semi-volatiles, and pesticide/PCBs were not detected in the 1986 and 1987 landfill pond samples. As shown in Table 5-3, radionuclide concentrations were detected but did not exceed the water quality criteria. The only trace metals exceeding the surface water quality criteria were manganese and iron. Total dissolved solids (TDS) also exceeded the surface water quality criterion. Elevated TDS, iron and manganese are typical of landfill leachate.

Table 5-3 also provides a comparison to surface water concentrations to ground-water alluvial concentrations upgradient of the landfill retention pond quality criteria. Ground-water chemistry is fully discussed in Section 4. The results of this comparison are discussed below.

The most notable difference between the water quality in the landfill pond and the ground water within the landfill is the relatively higher concentrations of magnesium, sodium, potassium, chloride, and TDS. This may be due to the leaching of these constituents from the soils south of the pond because of the spraying activities. Other analyte concentrations are similar in the pond and upgradient ground water. It would appear based on chemistry that interconnection of the ground

TABLE 5-2

SURFACE WATER QUALITY CRITERIA

METALS Analyte	CDH Water Quality Limited Standard (mg/l)	SDWA MCL (mg/l)	Water Quality Criteria (to be applied to Rocky Flats Plant site)
Aluminum	0.95		0.95 mg/l
Antimony			NS
Arsenic	0.05	0.05	0.05 mg/l
Barium	1.0	1.0	1.0 mg/l
Beryllium	0.1		0.1 mg/l
Cadmium	0.01	0.01	0.01 mg/l
Chromium III	0.05		0.05 mg/l
Chromium VI	0.05	0.05	0.05 mg/l
Cobalt			NS
Copper	1.0		1.0 mg/l
Lead	0.05	0.05	0.005 mg/l
Iron	0.3		0.3 mg/l
Manganese	0.05		0.05 mg/l
Mercury	0.002	0.002	0.002 mg/l
Molybdenum			NS
Nickel	0.05		0.05 mg/l
Selenium	0.01	0.01	0.01 mg/l
Silver	0.05	0.05	0.05 mg/l
Strontium			NS
Thallium	0.015		0.015 mg/l
Vanadium			NS
Zinc	5.0		5.0 mg/l

TABLE 5-2
(CONTINUED)

SURFACE WATER STANDARDS AND CRITERIA

RADIONUCLIDES Analyte	CDH Water Quality Limited Standard (mg/l)	SDWA MCL (mg/l)	Water Quality Criteria (to be applied to Rocky Flats Plant site)
Gross Alpha		15 pCi/l	15 pCi/l
Gross Beta		50 pCi/l	50 pCi/l
$Pu^{238, 239, 240}$		40 pCi/l*	40 pCi/l
Am^{241}		4 pCi/l*	4 pCi/l
H^3		20000 pCi/l	20000 pCi/l
$Uranium^{total}$			40** pCi/l
Major Ions			
pH	6.5-9.0		6.5-9.0
Nitrate	10.0		10.0 mg/l
Chloride	250		250 mg/l
Sulfate	250		250 mg/l
Cyanide (total)	0.200		0.200 mg/l
TDS		500***	500*** mg/l

* Proposed value in drinking water yielding a risk equal to that from a dose rate of 4 mrem/yr. September 30, 1986 (51FR34859).

** CDH Water Quality Standard for Surface Water [5CCR 1002-8, Section 3.8.5(3)]

*** SDWA Secondary Maximum Concentration Limit (SMCL)

NS = No standard

TABLE 5-3

ANALYTE CONCENTRATIONS IN LANDFILL POND COMPARED TO SURFACE WATER CRITERIA AND UPGRADIENT GROUND WATER CHEMISTRY

Analyte	Surface Water Concentration Range *	Upgradient Ground Water Concentration Range **	Surface Water Quality Criteria
METALS (mg/l)			
Silver	<0.01	<0.01	0.05
Aluminum	0.120-0.704	.029-.051	0.95
Arsenic	<0.01	<0.005	0.05
Barium	<0.1-.58	0.15-0.25	1.00
Beryllium	<0.005	<0.005	0.1
Cadmium	<0.005	<0.001	0.01
Cobalt	<0.05	<0.02-.03	NS
Chromium	0.011-0.019	<0.01-.03	0.05
Cesium	<0.2	<0.02	NS
Copper	<0.02	<0.006-.057	1.0
Iron	<0.03-2.3	0.047-.950	0.3
Mercury	<0.0002-0.00063	<0.0002	0.002
Mangenese	0.06-0.42	.64-1.6	0.05
Molybdenum	<0.1	<0.02-.36	NS
Nickel	<0.04	<.037-.044	0.05
Lead	<0.005	<0.005	0.005
Antimony	<0.05	<0.02	NS
Selenium	<0.005	<0.005	0.01
Strontium	0.4-1.05	.20-.69	NS
Thallium	<0.01	<0.01	0.015
Vanadium	<0.024	<0.024	NS
Zinc	<0.02-.89	.05-.11	5.0
MAJOR IONS (mg/l)			
Calcium	40-100	32-123	NS
Magnesium	21-75	5-15	NS
Sodium	75-226	19-33	NS
Potassium	9-68	3-4	NS
Chloride	91-124	5-26	250
Sulfate	8-52	8-139	250
Bicarbonate	190-402	107-392	NS
Nitrate	<0.2	<0.02-2.12	10
TDS	533-1082	226-519	500

TABLE 5-3 continued

ANALYTE CONCENTRATIONS IN LANDFILL POND COMPARED TO SURFACE WATER CRITERIA AND UPGRADIENT GROUND WATER CHEMISTRY

Analyte	Surface Water Concentration Range *	Upgradient Ground Water Concentration Range **	Surface Water Quality Criteria
RADIONUCLIDES (pCi/l)			
Gross Alpha	0(7)-23(11)	1(4)-17(7)	15
Gross Beta	11(5)-27(22)	-1(12)-16(11)	50
Plutonium	0.00(.97)-0.02(.05)	0.00(.16)-.21(.22)	40
Uranium 233 + 234	0.0(2.0)-1.1(.2)	0.05(.10)-4.6(.4)	40
Uranium 238	0.00(.55)-1.0(.2)	0.16(.10)-3.6(.3)	40
Americium	0.00(.51)-0.04(.04)	0.00(.09)-0.00(.71)	4
Tritium	110(220)-440	<220-1900	20,000

* Based on August 1986 and September 1987 data

** Based on January 1988 data for wells 63-87, 64-87, and 68-87 water and surface water exists. Further, the potentiometric surface map indicates the water table is at or near the retention pond elevation, and movement of ground water from the landfill is toward the retention pond.

5.3 Summary of Historical Water Quality Data

Appendix D presents historical chemical data for the west and east landfill ponds, landfill seepage, and the ground-water intercept system. The west landfill pond was removed in 1981 to allow eastward expansion of the landfill and was subsequently filled with waste. The east landfill pond is the pond that exists today.

5.3.1 Landfill Ponds

Comparison of the gross alpha, gross beta, tritium, nitrate, pH, total organic carbon (TOC), conductivity, chemical oxygen demand (COD), metals, and TDS data that exist for the west and east ponds show the water quality to be similar. This suggests that the leachate/ground water that entered the west pond also entered the east pond. It is noted that both gross alpha and gross beta exceeded, at times, the water quality criteria in both ponds. Also tritium, at times, was elevated (on the order of 1,000 pCi/l) which would appear to be related to the known disposal of tritium in the landfill. As shown in Table 5-4, tritium concentrations in the west pond during the years 1974 through 1977 are higher than in subsequent years (they are nevertheless below the surface water quality criterion). Gross alpha, gross beta, and tritium were lower during the 1986 sampling of the east pond relative to the historical data. There are inadequate data to interpret the significance of this finding; however, in general there are no apparent historical trends in water quality for the east landfill pond (or west landfill pond with the exception of tritium). The absence of a trend also applies to metal concentrations in both ponds. Lastly, the

TABLE 5-4

TRITIUM ANALYSES - LANDFILL POND NO. 1*

	1974 (pCi/l)	1975 (pCi/l)	1976 (pCi/l)	1977 (pCi/l)
January	-	1143	1740	1365
February	-	1429	1733	922
March	7922	1837	1323	1303
April	-	924	1431	1113
May	-	1445	1121	-
June	5875	984	1172	-
July	4797	1520	1378	-
August	3724	1258	1305	-
September	5056	1777	1143	-
October	3304	1762	869	-
November	1800	1553	1005	-
December	-	1542	1067	-

* Landfill Pond No. 1 = West Pond; Data reproduced verbatim from a file of historical data. Source unknown.

TDS, gross alpha, gross beta, metal, and nitrate concentrations are similar to those observed for ground water within the landfill. It is concluded that future changes in water quality of the east pond or ground water within the landfill are unlikely based on this data.

5.3.2 Landfill Seepage

It would appear that "seepage" from the landfill contained higher metal concentrations and possibly volatile organic compounds that are not observed in the west pond, east pond, or ground water within the landfill. Table 5-5, constructed from a 1973 Dow Chemical Lab report on what was termed "landfill seepage", shows the presence of freon, chloroform, chlorothene, carbon tetrachloride, trichloroethene, and tetrachloroethene. The seepage also contained high concentrations of calcium, magnesium, sodium manganese, and iron relative to that observed in the west or east ponds, or the ground water within the landfill. It would appear this seepage is a concentrated leachate that ultimately mixed with runoff and ground water in the west (and east) ponds producing the water quality seen in the ponds. However, the VOC's have never been observed in the ponds or ground water at the landfill.

As discussed in Section 4, the most significant water quality change in ground water within the landfill is elevated calcium, bicarbonate, iron, and manganese. The seepage has these same characteristics but these compounds are at considerably higher concentrations than observed in the ground water within the landfill. It is conjectured that in the early 1970's there was less water within the landfill and thus current landfill ground water chemical conditions reflect a mixture of ground water and this "leachate".

TABLE 5-5

SANITARY LANDFILL SEEPAGE
CHEMICAL CHARACTERISTICS*

ANALYTE	CONCENTRATION (mg/l)
ORGANICS	
Freon	1.2
Chloroform	0.1
Chloroethene	0.05
Carbon Tetrachloride	0.005
Trichloroethylene	0.50
Perchloroethylene	0.05
Pesticides	0.001
METALS	
Silver	0.005
Aluminum	0.4
Barium	<1
Cadmium	0.001
Cobalt	0.018
Chromium	<0.005
Copper	0.06
Iron	60
Mercury	<0.001
Manganese	3.4
Molybdenum	1.0
Nickel	0.06
Lead	0.008
Antimony	<0.01
Selenium	<0.01
Tin	<0.05
Thallium	<0.0025
Vanadium	<1.0
Zinc	0.061
MAJOR IONS	
Calcium	400
Magnesium	125
Sodium	205
Potassium	8.5
Sulfate	12
Chloride	4.8
Bicarbonate	1670
Total Solids	2400

* Source = Dow Chemical Laboratory Report M73-1752, 01/14/73

5.3.3 Ground-Water Intercept System

Historical gross alpha, tritium, and nitrate data exist for ground water discharging from the north and south ground-water intercept systems (data coded as the north and south landfill bypass). Concentrations of gross alpha and tritium are similar to the concentrations observed for ground water within the landfill. Nitrate concentrations in ground water from the north intercept system (on the order of 3-4 mg/l) are similar to ground water within the landfill; however, nitrate concentrations in ground water for the south interceptor system are higher (on the order of 6-10 mg/l). It is not known why elevated nitrates occur in ground water of the south intercept system but do not occur within the landfill. As discussed in Section 4, ground-water quality within the landfill, which is ostensibly impacted by the landfill, is within the ground-water quality variations observed in the general area. Therefore, this limited data do not provide additional useful information to interpret whether the ground-water intercept system is functioning.

SECTION 6

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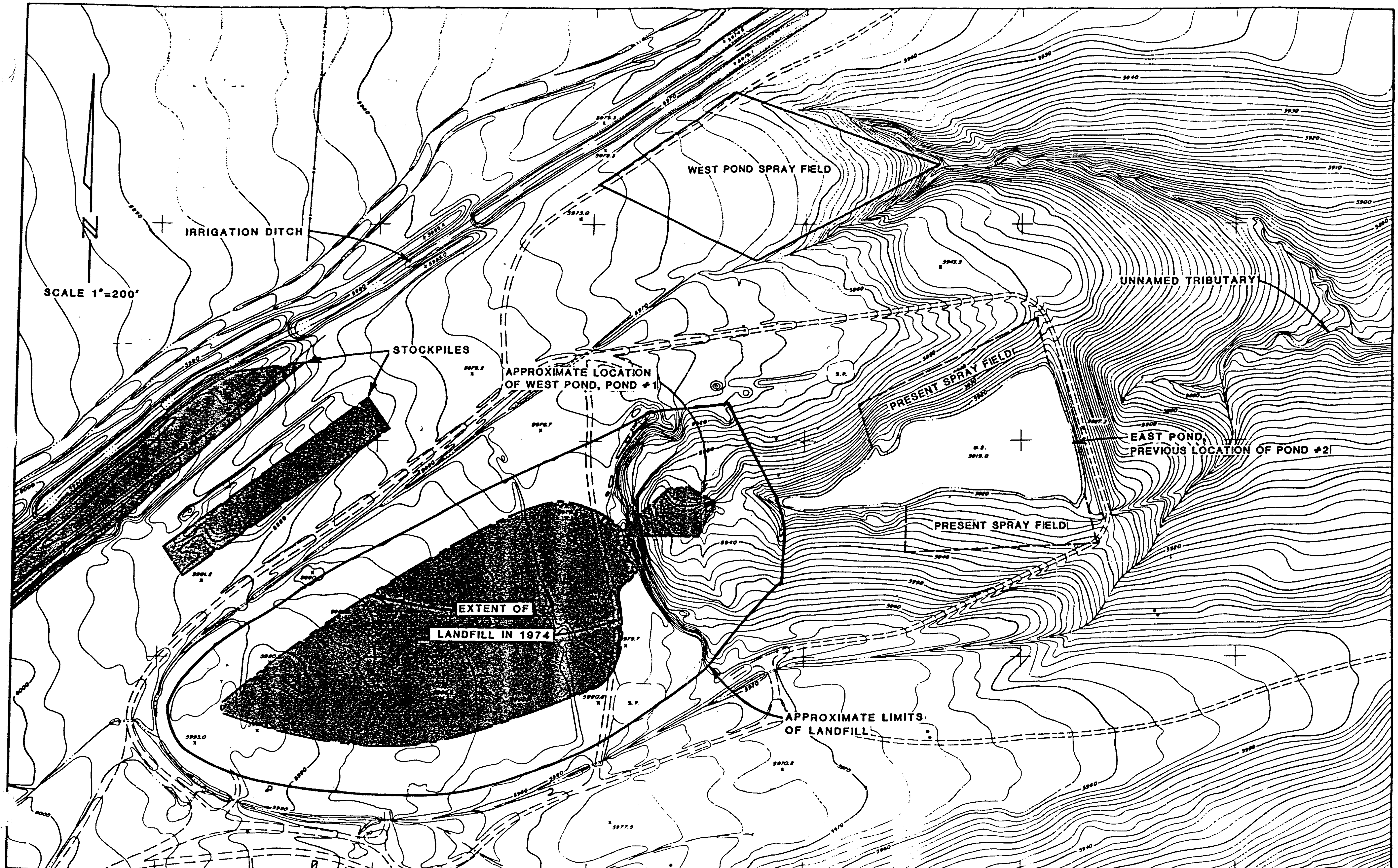
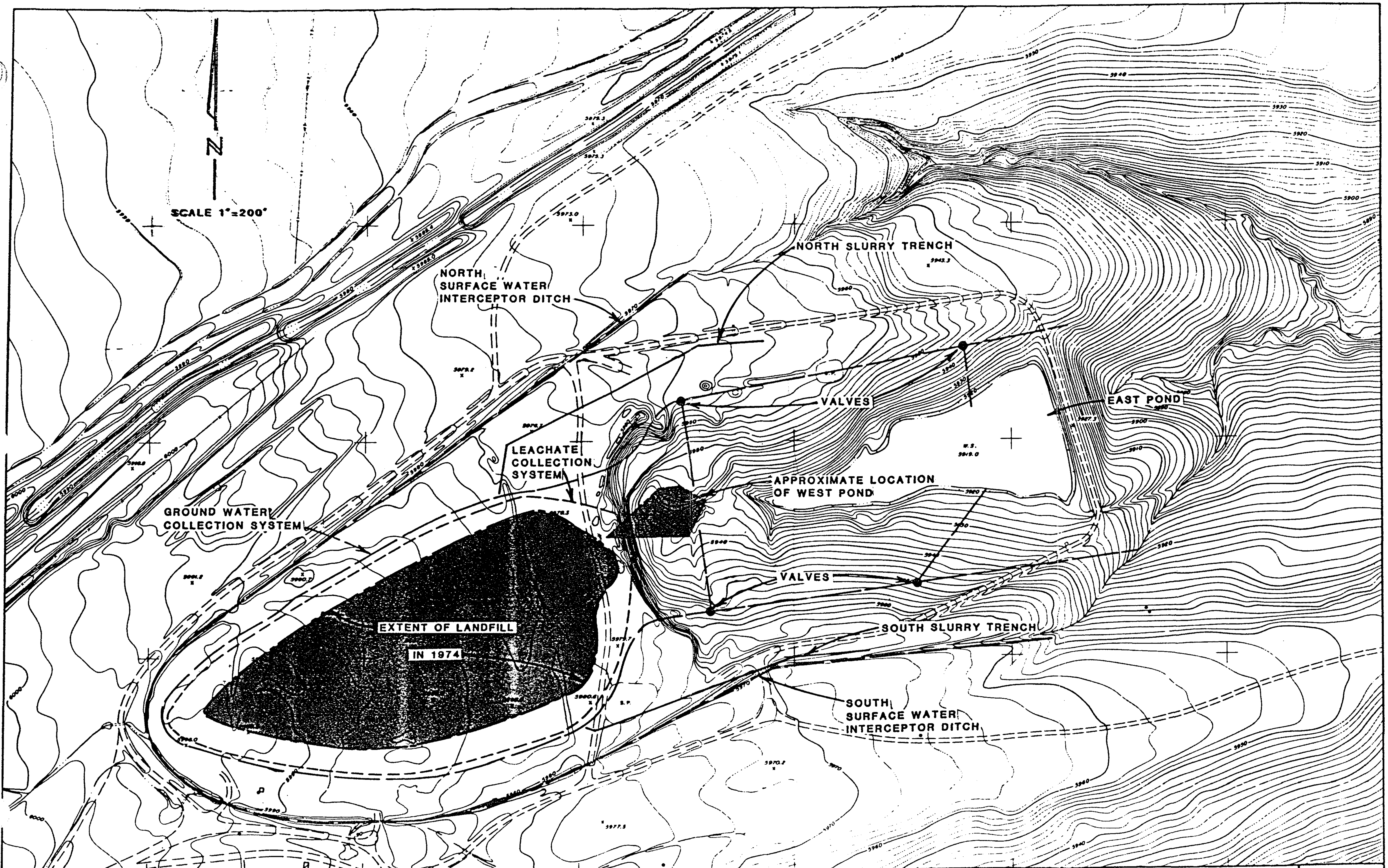
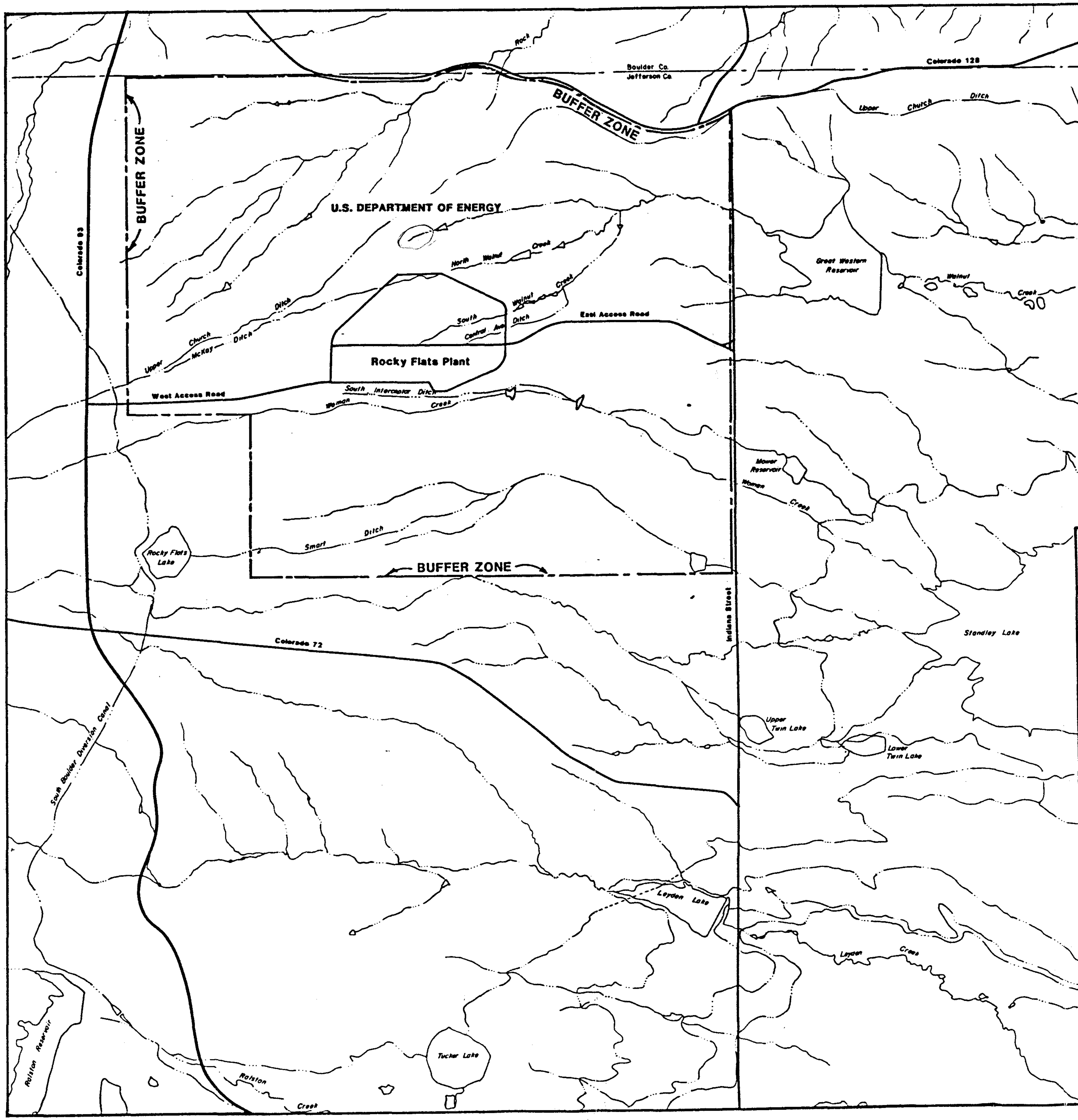


6 032 88	Chen & Associates	PRESENT LANDFILL SITE MAP	Fig. 2-3



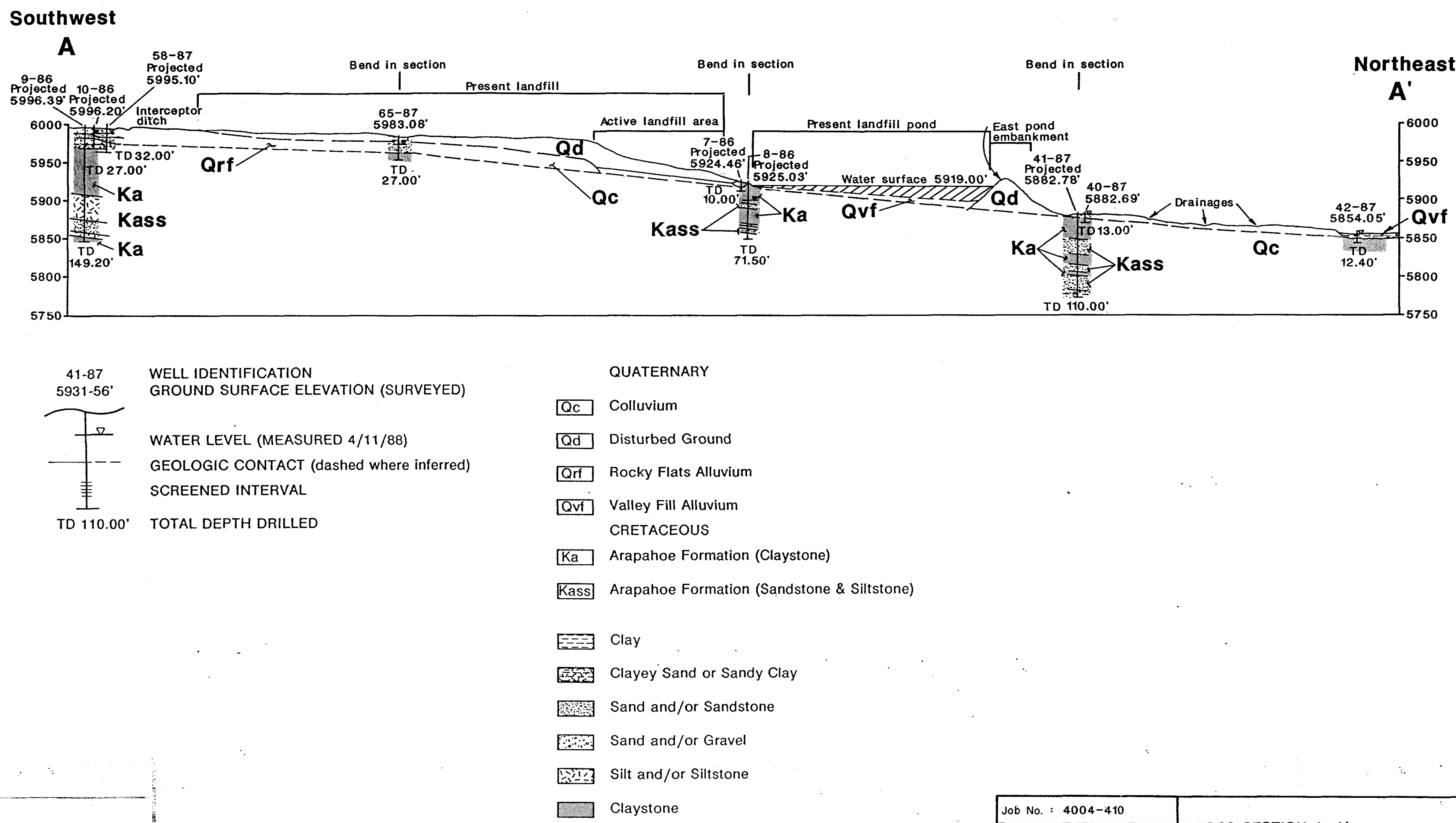
6 032 88 | Chen & Associates | PRESENT LANDFILL COLLECTION SYSTEMS | Fig. 2-4



(after: U.S.G.S. Quads., Louisville, 1979, Golden, 1980, Lafayette, 1979)

Figure 2-2:

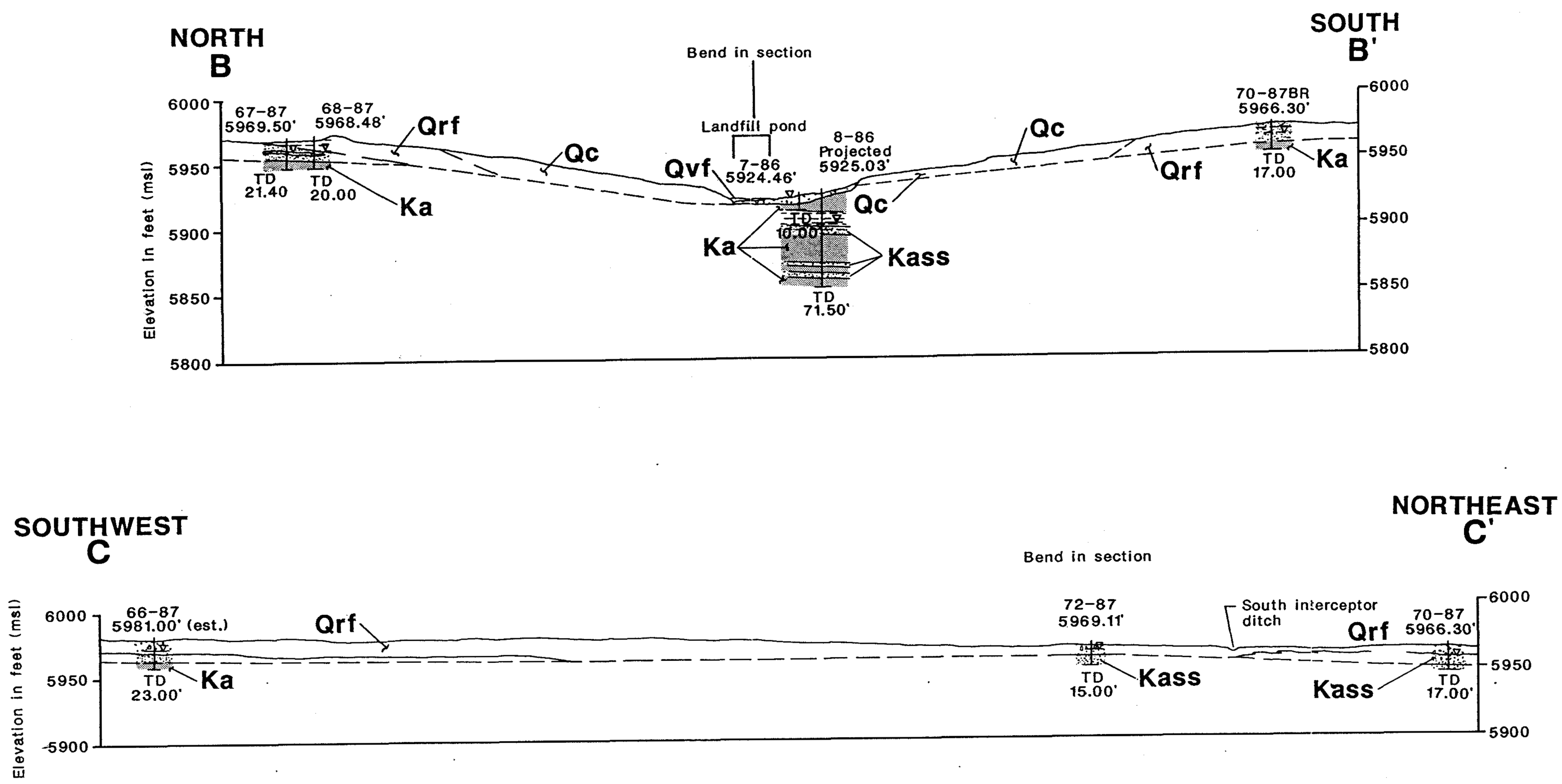
Rocky Flats Plant Boundaries and Buffer Zone



SOURCE: ROCKWELL INTERNATIONAL 1988d

Job No. : 4004-410	CROSS SECTION A-A'
Prepared by : A.C.	
Date : 5/4/90	Figure 2-2

134376



41-87 5931-56' — WELL IDENTIFICATION, GROUND SURFACE ELEVATION (SURVEYED)

WATER LEVEL (MEASURED 4/11/88)

GEOLOGIC CONTACT (dashed where inferred)

SCREENED INTERVAL

TD 110.00' — TOTAL DEPTH DRILLED

CRETACEOUS

- Ka — Arapahoe Formation (Claystone)
- Kass — Arapahoe Formation (Sandstone & Siltstone)
- Clay
- Clayey Sand or Sandy Clay
- Sand and/or Sandstone
- Sand and/or Gravel
- Silt and/or Siltstone
- Claystone

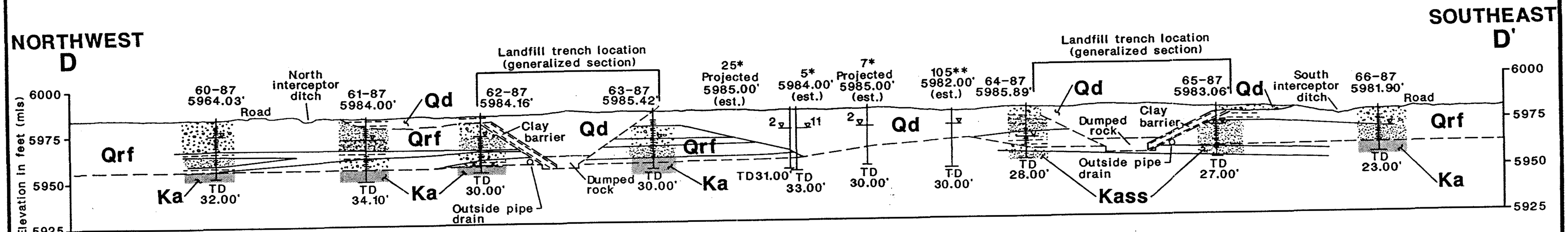
QUATERNARY

- Qc — Colluvium
- Qd — Disturbed Ground
- Qrf — Rocky Flats Alluvium
- Qvf — Valley Fill Alluvium

SOURCE: ROCKWELL INTERNATIONAL 1988d

Job No. : 4004-410	CROSS SECTION B-B' AND C-C'
Prepared by : A.C.	
Date : 5/4/90	Figure 2-3

134376



2 Fill water level and number of days after drilling that measurement was taken

*Woodward-Clevenger & Associates (1974) Test hole

**Zeff et al (1974) Test hole

41-87 5931-56'	WELL IDENTIFICATION GROUND SURFACE ELEVATION (SURVEYED)
	WATER LEVEL (MEASURED 4/11/88)
	GEOLOGIC CONTACT (dashed where inferred)
	SCREENED INTERVAL
TD 110.00'	TOTAL DEPTH DRILLED

QUATERNARY

Qc	Colluvium
Qd	Disturbed Ground
Qrf	Rocky Flats Alluvium
Qvf	Valley Fill Alluvium

CRETACEOUS

Ka	Arapahoe Formation (Claystone)
Kass	Arapahoe Formation (Sandstone & Siltstone)

- Clay
- Clayey Sand or Sandy Clay
- Sand and/or Sandstone
- Sand and/or Gravel
- Silt and/or Siltstone
- Claystone

SOURCE: ROCKWELL INTERNATIONAL 1988d

Job No. : 4004-410	CROSS SECTION D-D'
Prepared by : A.C.	
Date : 5/4/90	Figure 2-4

CROSS SECTION D-D'

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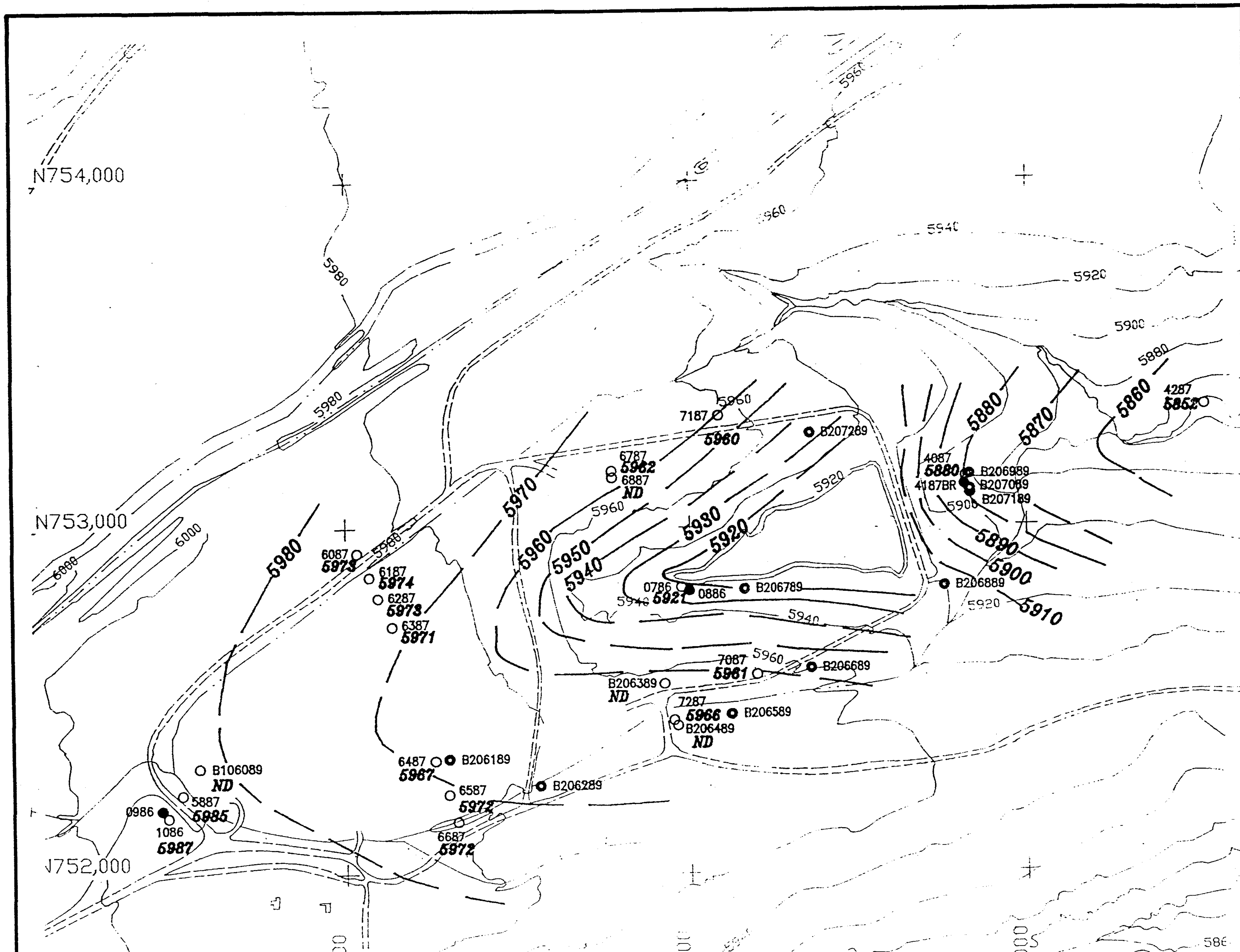


LEGEND

B301889 ○	Alluvial Monitoring Well
B206889 ⊙	Weathered Bedrock Monitoring Well
B207189 ●	Unweathered Bedrock Monitoring Well
5960	Potentiometric Surface Elevation May 1989 (feet above mean sea level)
5920	Line of Equal Potentiometric Surface Elevation (feet above mean sea level) Dashed where approximately located Contour Interval – 10 feet
ND	No Data

Scale: 1" = 300'

0' 150' 300'

CONTOUR INTERVAL = 20'

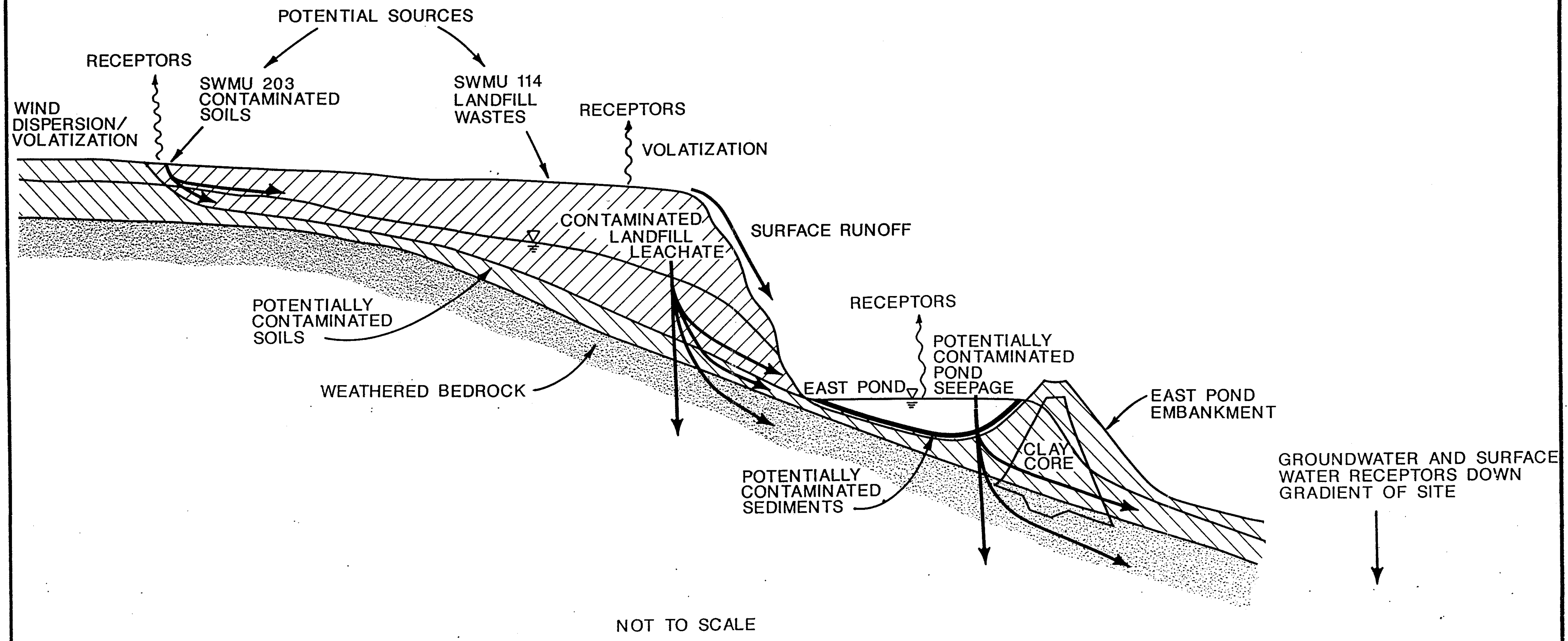
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

PRESENT LANDFILL AREA
1989 RCRA GROUNDWATER
MONITORING REPORT

SOURCE: EG&G, 1990a

Job No. : 4004-410	MAY 1989 POTENTIOMETRIC SURFACE MAP
Prepared by : A.C.	
Date : 5/4/90	Figure 2-9

134376



Job No. : 4004-410	PRESENT LANDFILL SITE CONCEPTUAL MODEL
Prepared by : A.C./T.K.	
Date : 5/4/90	Figure 2-11

134376

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	DESCRIPTION
TREATMENT	SOLIDS PROCESSING	SOLIDS PROCESSING PREPARES SOLID WASTES FOR FURTHER TREATMENT OR DISPOSAL BY SIZE REDUCTION OR CLASSIFICATION OR MATERIAL SEPARATION.
	SOLIDS TREATMENT	SOILS, SEDIMENTS, AND OTHER SOLIDS ARE PHYSICALLY OR CHEMICALLY TREATED TO REMOVE THE HAZARDOUS AND RADIOACTIVE CONSTITUENTS OR CONVERT THE CONSTITUENTS TO NONHAZARDOUS SUBSTANCES.
	SOLIDIFICATION, FIXATION, STABILIZATION	STABILIZATION AND FIXATION PROCESSES MAINTAIN HAZARDOUS AND RADIOACTIVE CONSTITUENTS IN THEIR LEAST TOXIC AND/OR LEAST MOBILE FORM. SOLIDIFICATION PRODUCES A MONOLITHIC BLOCK OF TREATED WASTE WITH HIGH STRUCTURAL INTEGRITY.
	SOLIDS DEWATERING	SOLID/LIQUID SEPARATION RECOVERS SOLIDS AND LIQUIDS, OR REMOVES EXCESS LIQUID FROM SEDIMENTS AND SLUDGES PRIOR TO DISPOSAL.
	PHYSICAL TREATMENT	LIQUIDS CONTAINING HAZARDOUS CHEMICALS OR RADIOACTIVE CONSTITUENTS ARE TREATED TO CONVERT THE CONSTITUENTS TO A MORE EASILY HANDLED FORM THROUGH EQUALIZATION, CONCENTRATION, AND/OR PHASE CHANGE.
	CHEMICAL TREATMENT	LIQUIDS CONTAINING HAZARDOUS CHEMICALS OR RADIOACTIVE CONSTITUENTS ARE ALTERED BY CHEMICAL REACTIONS TO DETOXIFY HAZARDOUS CHEMICALS OR TO CONVERT THE CHEMICALS OR RADIONUCLIDES TO A MORE EASILY TREATED FORM.
	BIOLOGICAL TREATMENT	A CULTURE OF MICROORGANISMS METABOLIZES BIODEGRADABLE ORGANIC MATERIALS.
	THERMAL TREATMENT	WASTES ARE EXPOSED TO HIGH TEMPERATURES TO TRANSFORM THE HAZARDOUS COMPOUNDS INTO INNOCUOUS OR LESS HARMFUL SUBSTANCES. THERMAL TREATMENT WILL NOT DECREASE RADIOACTIVITY.
	AIR EMISSIONS CONTROL & TREATMENT	VAPOR PHASE IMPURITIES ARE REMOVED FROM LANDFILL GASES THROUGH PROCESSES RANGING FROM ONCE-THROUGH WASH OPERATIONS TO MULTIPLE-STEP RECYCLE SYSTEMS.
IN SITU TREATMENT	IN SITU TREATMENT	PHYSICAL, CHEMICAL, AND BIOLOGICAL PROCESSES ARE EMPLOYED TO TREAT CONTAMINATED SOIL, SOLID WASTES OR GROUNDWATER IN PLACE.
DISPOSAL	RESOURCE RECOVERY	CERTAIN MINERALS, METALLIC PRODUCTS AND RADIOISOTOPES CAN BE RECLAIMED FROM HAZARDOUS/RADIOACTIVE WASTES AND REUSED.
	LAND APPLICATION	LIQUID AND SOLID WASTES THAT ARE PRIMARILY ORGANIC ARE INCORPORATED INTO THE UPPER SOIL HORIZON SO THEY CAN BE DEGRADED, TRANSFORMED, OR IMMOBILIZED.
	NUCLEAR WASTE REPOSITORY	RADIOACTIVE WASTES ARE DISPOSED OF IN A LICENSED LOW LEVEL OR HIGH LEVEL RADIOACTIVE WASTE REPOSITORY.
	WASTEWATER DISCHARGE	AQUEOUS STREAMS ARE DISCHARGED TO A TREATMENT PLANT, SURFACE WATER, OR SHALLOW OR DEEP WELLS.
	LANDFILL	SOLID WASTES ARE PERMANENTLY DISPOSED OF IN A LANDFILL. LANDFILLS CANNOT ACCEPT LIQUID WASTES.
MONITORING	MONITORING	SHORT-AND/OR LONG-TERM MONITORING IS IMPLEMENTED TO ASSESS SITE CONDITIONS AND CONTAMINATION LEVELS.

GY DESCRIPTION

134376

Job No. : 4004-410	REMEDIAL TECHNOLOGY DESCRIPTION
Prepared by : A.C./T.K.	
Date : 5/4/90	Figure 3-2

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	DESCRIPTION
NO ACTION	NONE	NO ACTION; REMEDIAL RESPONSES INITIATED AT SITE ARE ABANDONED; NO MONITORING.
ACCESS AND USE RESTRICTIONS	ACCESS AND USE RESTRICTIONS	EXAMPLES INCLUDE LEGAL RESTRICTIONS ON DEEDS TO REGULATE LAND USE; PERMITS TO REGULATE GROUNDWATER USE; FENCES TO REGULATE SITE ACCESS; SIGNS TO WARN POTENTIAL INTRUDERS.
CONTAINMENT	CAPPING	IMPERMEABLE COVER MATERIALS ARE PLACED OVER WASTE DISPOSAL AREAS AND CONTAMINATED SOILS TO REDUCE OR ELIMINATE INFILTRATION, PREVENT EROSION, AND TO PROVIDE INTRUSION BARRIER.
	VERTICAL BARRIERS	WALLS THAT ARE LESS PERMEABLE THAN THE IN SITU SOIL ARE PLACED UPGRADIENT OR DOWNGRADIENT OF WASTE DISPOSAL AREAS, OR MAY BE USED TO ENCIRCLE WASTE DISPOSAL AREAS.
	INSITU BARRIERS	LOW-PERMEABILITY MATERIAL IS PLACED INTO VOID SPACES TO REDUCE THE PERMEABILITY OF THE IN SITU WASTE OR SOIL.
	SURFACE CONTROLS	SURFACE SEALING, GRADING, SOIL STABLIZATION, REVEGETATION, AND SURFACE WATER DIVERSION/COLLECTION ARE IMPLEMENTED TO REDUCE SITE RUNON/RUNOFF, SURFACE WATER INFILTRATION AND EROSION, AND TO STABILIZE SURFACE SOILS.
	SEDIMENT CONTROL BARRIERS	A PHYSICAL BARRIER, FILTER SCREEN, OR CAP IS CONSTRUCTED TO MINIMIZE THE SPREAD OF CONTAMINANTS BY SEDIMENT MIGRATION.
	DUST AND VAPOR SUPPRESSION	TARPS, SOIL COVERS, SPRAYS, ETC. ARE APPLIED TO SUPPRESS DUST AND NON-POINT-SOURCE VAPOR.
PUMPING AND REMOVAL	BULK LIQUID PUMPING	BULK LIQUIDS IN OPEN PITS, OPEN PONDS, TANKS, DRUMS, ETC., ARE REMOVED BY A VARIETY OF METHODS, MOST COMMONLY BY PUMPING.
	GROUNDWATER PUMPING	GROUNDWATER AND LEACHATE ARE COLLECTED IN WELLS OR TRENCH DRAINS AND PUMPED SO THEY CAN BE TREATED AND DISPOSED.
	LANDFILL GAS COLLECTION	GASES EMANATING FROM WASTE DISPOSAL AREAS ARE INTERCEPTED BY A PASSIVE OR ACTIVE (PUMPED) SYSTEM.
	DRUM & DEBRIS REMOVAL	DRUMS AND/OR DEBRIS ARE REMOVED BY VARIOUS MECHANICAL MEANS, E.G., CRANES AND OTHER STANDARD CONSTRUCTION EQUIPMENT.
	EXCAVATION	CONTAMINATED SOIL, SEDIMENT, SLUDGES AND OTHER SOLIDS ARE REMOVED WITH STANDARD CONSTRUCTION EQUIPMENT.
	DECONTAMINATION	CONTAMINATED BUILDINGS, BUILDING MATERIALS OR OTHER STRUCTURES ARE WASHED WITH A SUBSTANCE THAT REMOVES CONTAMINANTS UPON RINSING. OFTEN DECONTAMINATION IS DONE WITH A PRESSURIZED STREAM.

Job No. : 4004-410

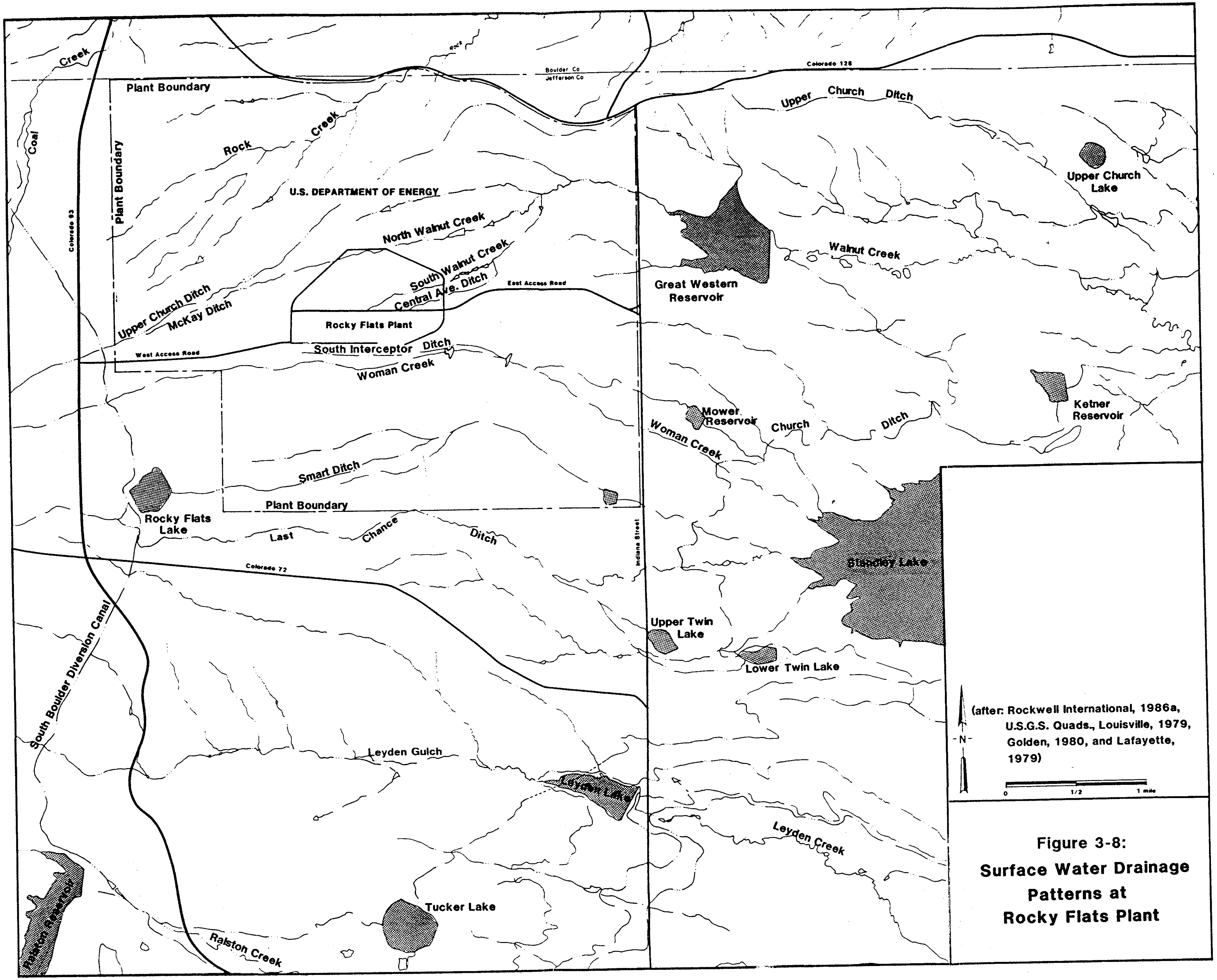
Prepared by : A.C.

Date : 5/4/90

REMEDIAL TECHNOLOGY DESCRIPTION

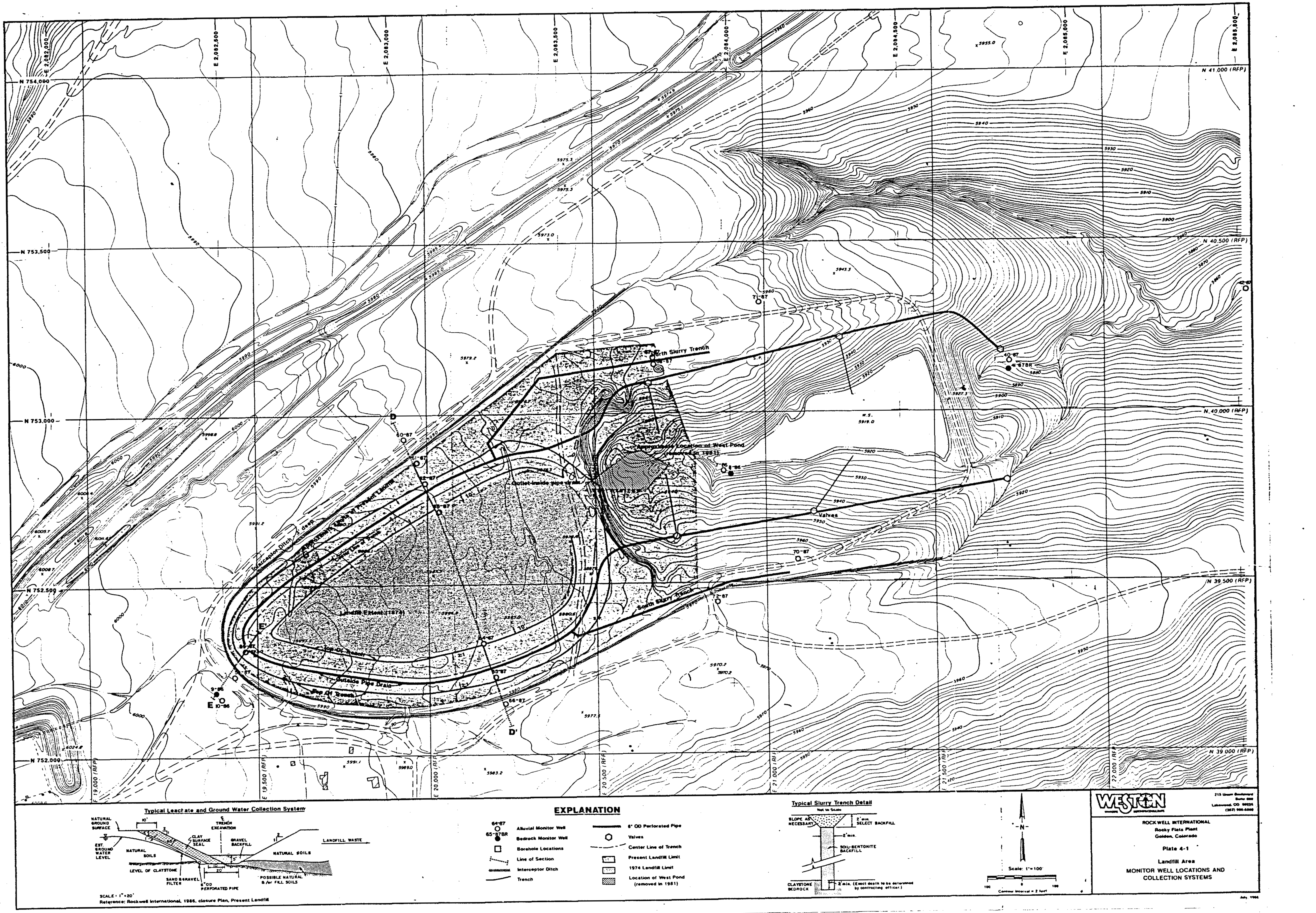
Figure 3-2 (continued)

134376



(after: Rockwell International, 1986a, U.S.G.S. Quads., Louisville, 1979, Golden, 1980, and Lafayette, 1979)

Figure 3-8: Surface Water Drainage Patterns at Rocky Flats Plant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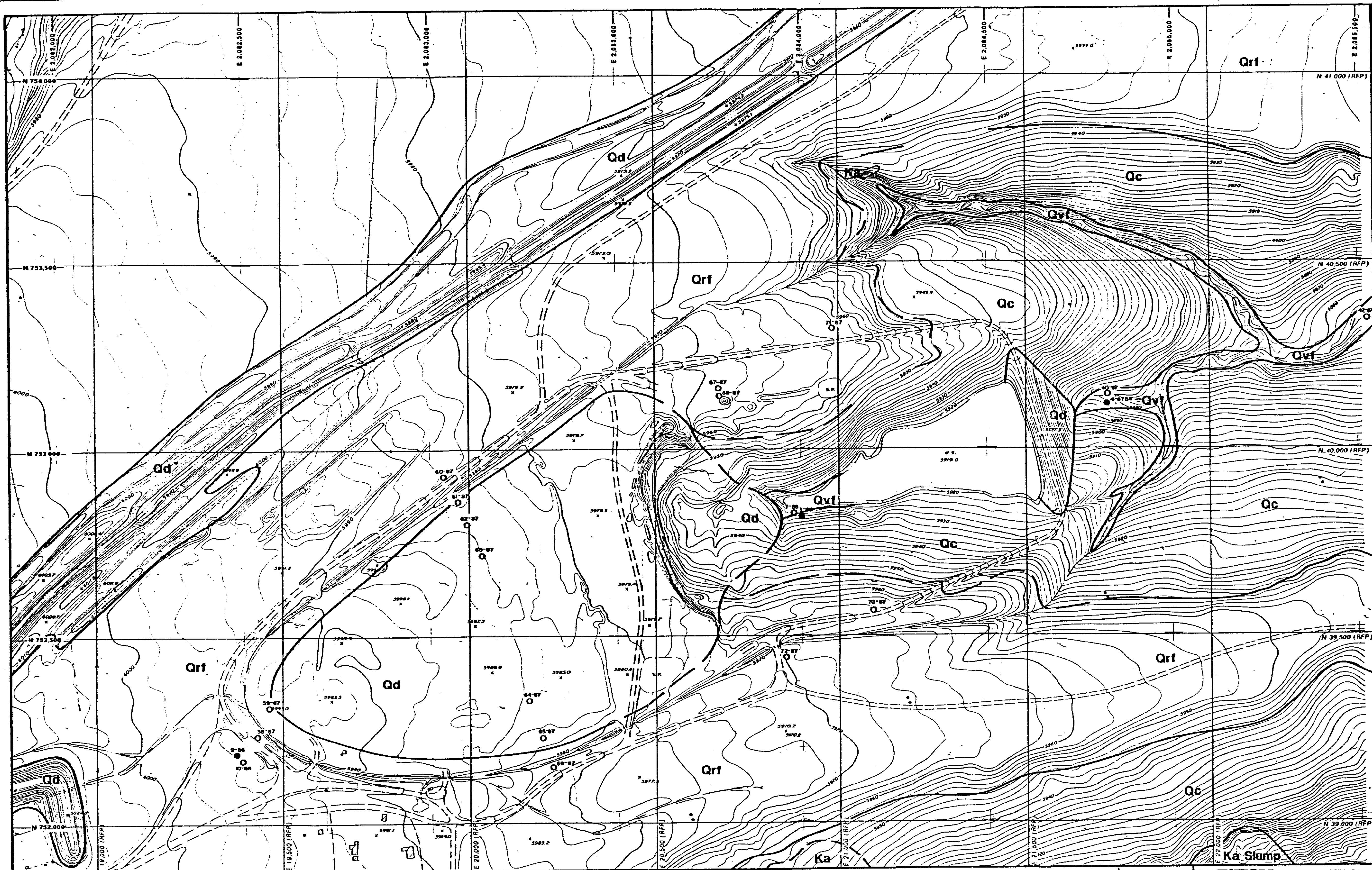
North Slurry Trench
South Slurry Trench
Approximate Location of West Pond (removed in 1981)
Outlet inside pipe drain
Valves
Interceptor Ditch
Landfill Extent (1974)
Outside Pipe Drain
Top Of Trench
W.S. 5919.0
Typical Leachate and Ground Water Collection System
NATURAL GROUND SURFACE
EST. GROUND WATER LEVEL
NATURAL SOILS
10'
TRENCH EXCAVATION
CLAY SURFACE SEAL
GRAVEL BACKFILL
LANDFILL WASTE
NATURAL SOILS
LEVEL OF CLAYSTONE
SAND & GRAVEL FILTER
6" OD PERFORATED PIPE
POSSIBLE NATURAL &/or FILL SOILS
SCALE: 1" = 20'
Reference: Rockwell International, 1986, closure Plan, Present Landfill
EXPLANATION
64-87 Alluvial Monitor Well
65-87BR Bedrock Monitor Well
Borehole Locations
Line of Section
Interceptor Ditch
Trench
6" OD Perforated Pipe
Valves
Center Line of Trench
Present Landfill Limit
1974 Landfill Limit
Location of West Pond (removed in 1981)
Typical Slurry Trench Detail
Not to Scale
SLOPE AS NECESSARY
2' min. SELECT BACKFILL
2' min.
SOIL-BENTONITE BACKFILL
CLAYSTONE BEDROCK
2' min. (Exact depth to be determined by contracting officer.)
N
Scale: 1" = 100'
100
0
100
Contour Interval = 2 feet
WESTON
ROCKWELL INTERNATIONAL
Rocky Flats Plant
Golden, Colorado
Plate 4-1
Landfill Area
MONITOR WELL LOCATIONS AND COLLECTION SYSTEMS
July, 1988



EXPLANATION

- 64-87 ○ Alluvial Monitor Well
- 63-87BR ● Bedrock Monitor Well
- □ Borehole Locations

Cretaceous

- Ka — Arapahoe Formation (Claystone)
- Kas — Arapahoe Formation (Sandstone)

Quarternary

- Qaf — Artificial Fill
- Qc — Colluvium
- Qd — Disturbed Ground
- Qrf — Rocky Flats Alluvium
- Qvf — Valley Fill Alluvium

N

Scale: 1"=100'

Contour Interval = 2 feet

WESTON

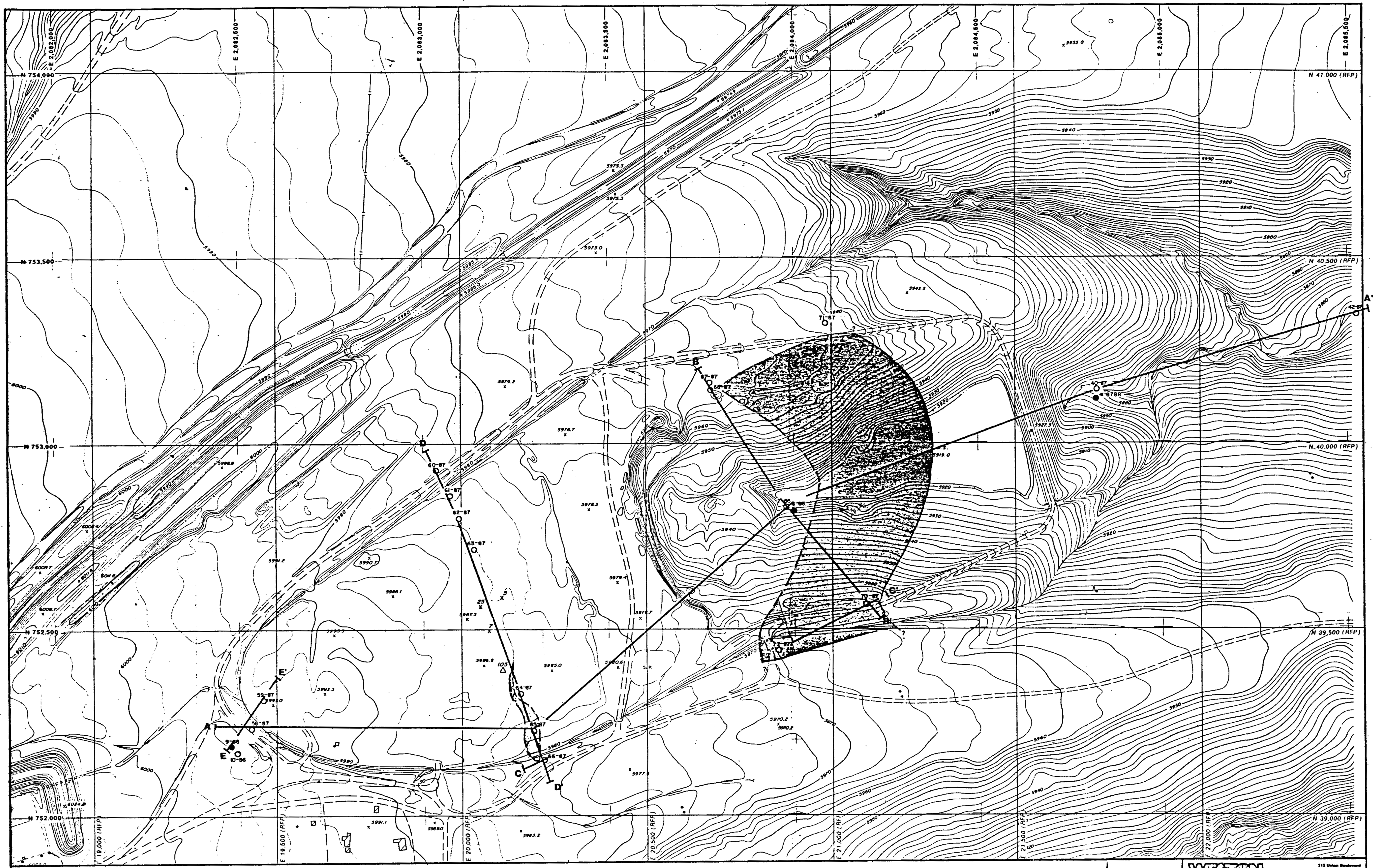
215 Union Boulevard
Suite 600
Lakewood, CO 80228
(303) 980-6800

ROCKWELL INTERNATIONAL
Rocky Flats Plant
Golden, Colorado

Plate 4-2

Landfill Area
SURFICIAL GEOLOGY MAP

July, 1988



EXPLANATION

64-87 ○ Alluvial Monitor Well

9-86 ● Bedrock Monitor Well

7 x Woodward-Clevenger and Associates (1974) Test Hole

105 △ Zeff et al, (1974) Test Hole

Line of Section

Subcropping Sandstone (estimated extent)

N

Scale: 1"=100'

Contour Interval = 2 feet

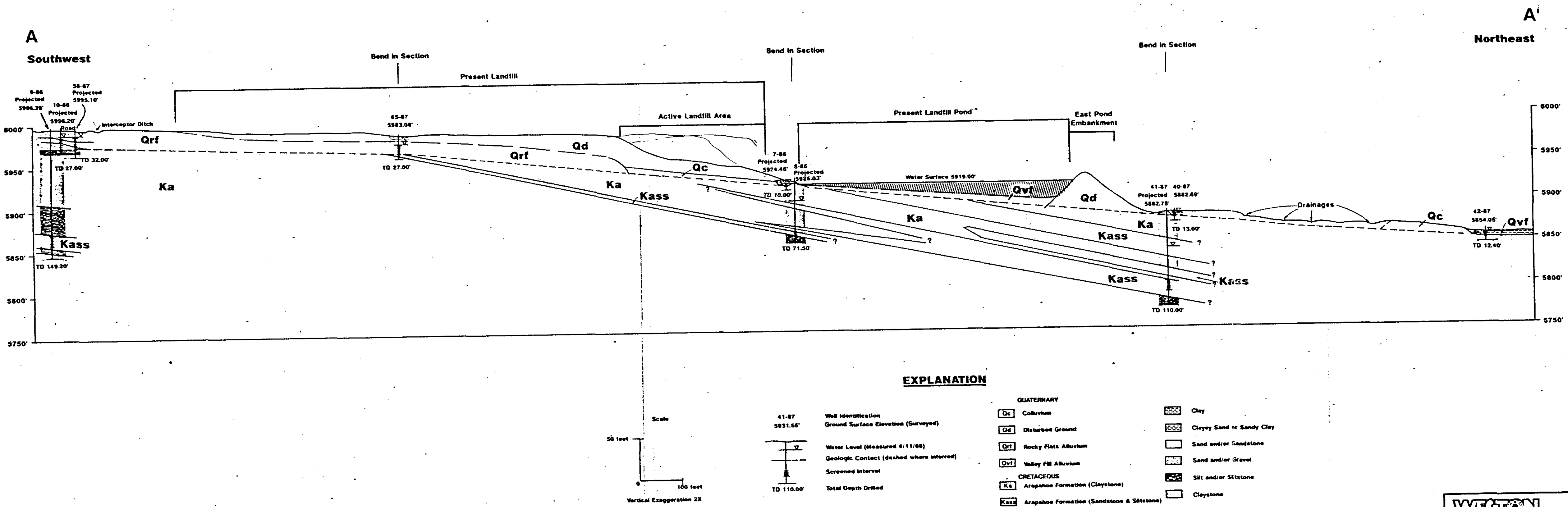
WESTON

ROCKWELL INTERNATIONAL
Rocky Flats Plant
Golden, Colorado

Plate 4-3

Landfill Area

CROSS SECTION LOCATION LINES AND SUBCROPPING SANDSTONE (Plan View) MAP



NOTE: 1986 Well locations resurveyed during 1988.
This plate reflects new locations and elevations.

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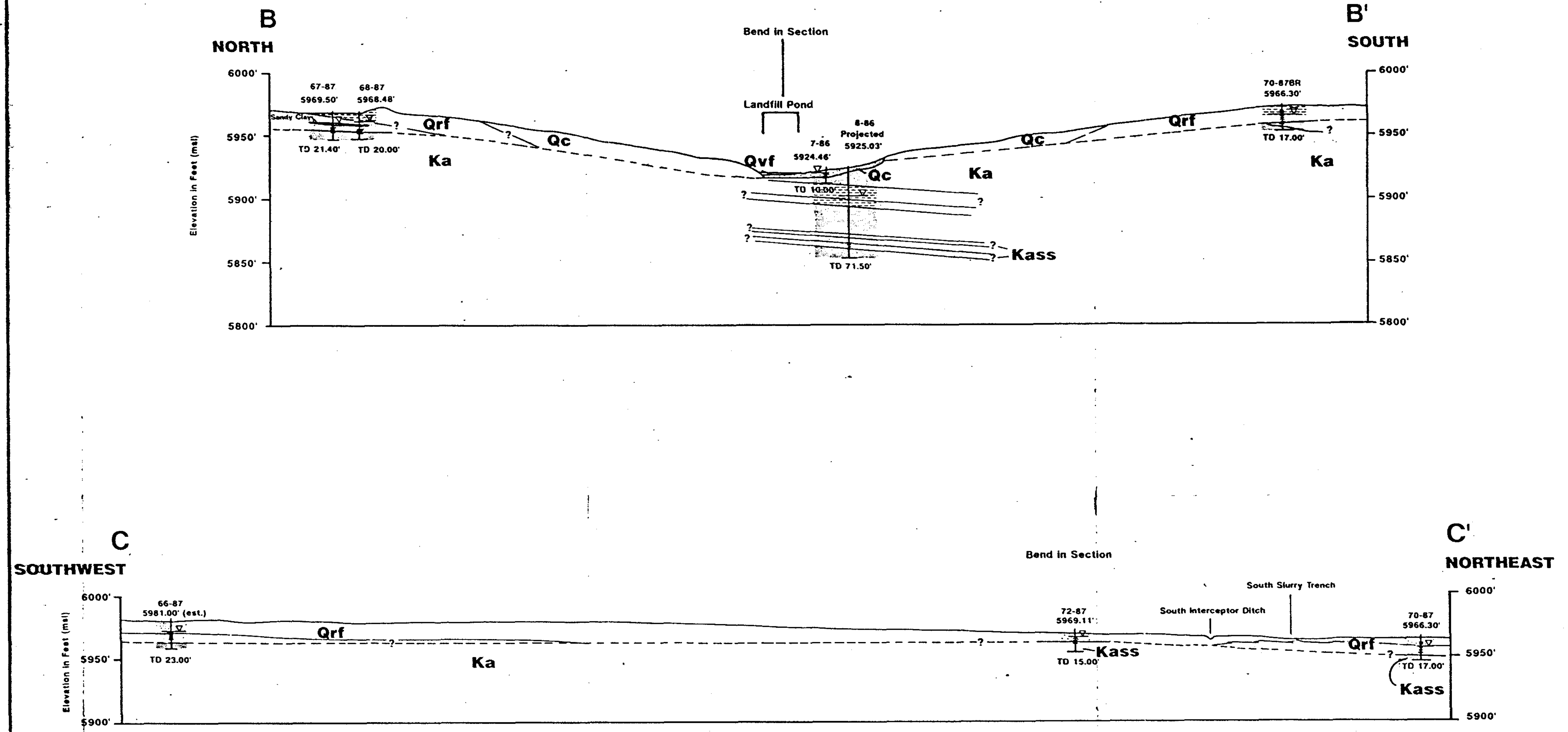
Golden, Colorado

Plate 4-4

Landfill Area
CROSS SECTION A-A'

July, 1988



EXPLANATION

Scale

50 feet

0 50 feet

No Vertical Exaggeration

41-87 Well Identification

5931.56' Ground Surface Elevation (Surveyed)

Water Level (Measured 4/11/88)

Geologic Contact (dashed where inferred)

Screened Interval

TD 110.00' Total Depth Drilled

QUATERNARY

Qc Colluvium

Qd Disturbed Ground

Qrf Rocky Flats Alluvium

Qvf Valley Fill Alluvium

CRETACEOUS

Ka Arapahoe Formation (Claystone)

Kass Arapahoe Formation (Sandstone & Siltstone)

Clay

Clayey Sand or Sandy Clay

Sand and/or Sandstone

Sand and/or Gravel

Silt and/or Siltstone

Claystone

NOTE: 1986 Well locations resurveyed during 1988.
This plate reflects new locations and elevations.

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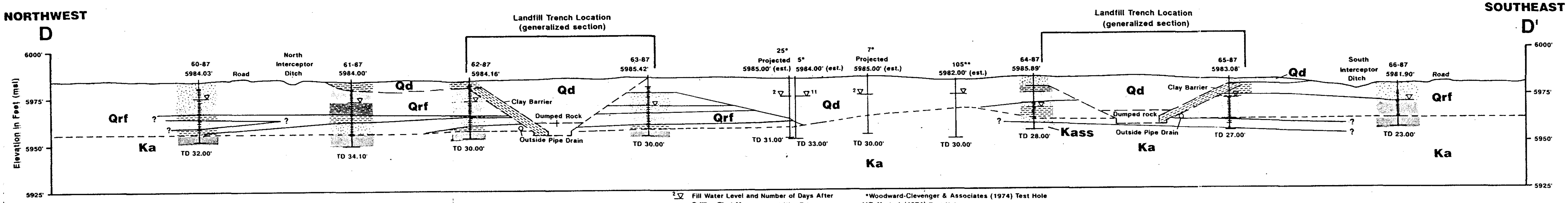
Plate 4-5

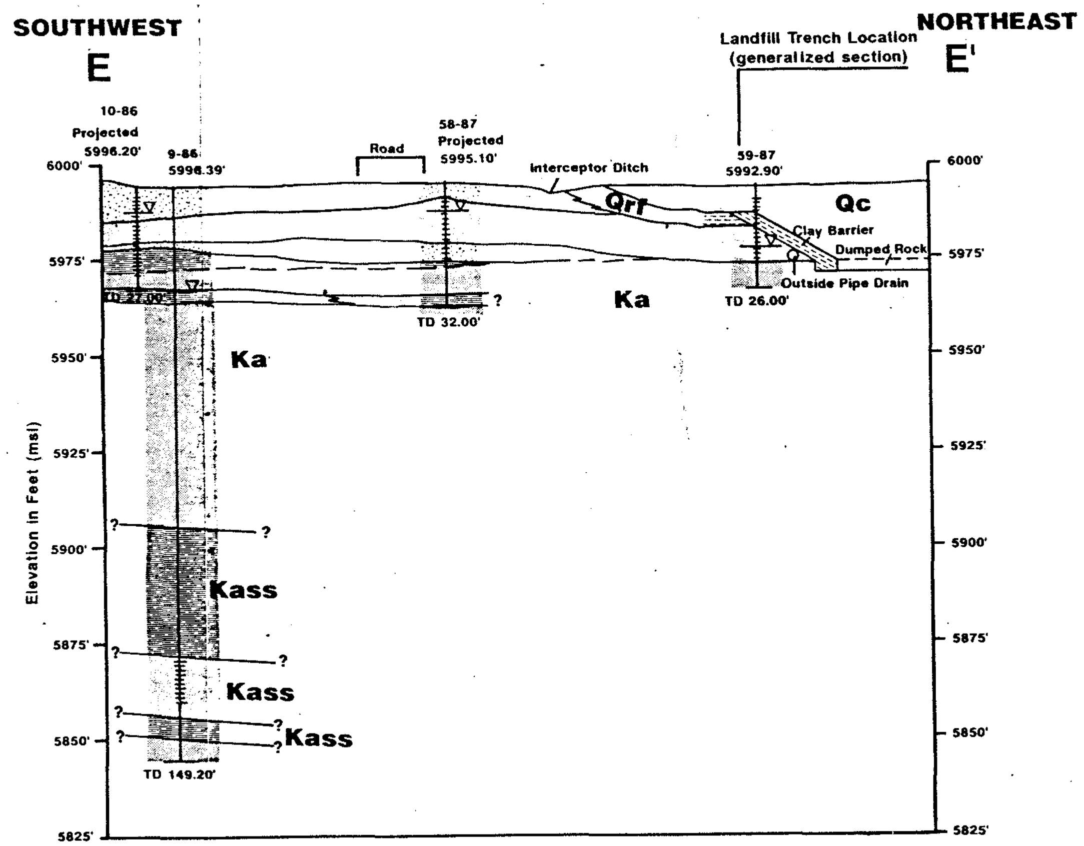
Landfill Area
CROSS SECTIONS B-B' & C-C'

July, 1988



2 ▽ Fill Water Level and Number of Days After Drilling That Measurement Was Taken

*Woodward-Clevenger & Associates (1974) Test Hole
**Zeff et al (1974) Test Hole



41-87 — Well Identification
5931.56' — Ground Surface Elevation (Surveyed)
Water Level (Measured 4/11/88)
Geologic Contact (dashed where inferred)
Screened Interval
TD 110.00' — Total Depth Drilled

QUATERNARY
- Qc — Colluvium
- Qd — Disturbed Ground
- Qrf — Rocky Flats Alluvium
- Qvf — Valley Fill Alluvium

CRETACEOUS
- Ka — Arapahoe Formation (Claystone)
- Kass — Arapahoe Formation (Sandstone & Siltstone)

- Clay
- Clayey Sand or Sandy Clay
- Sand and/or Sandstone
- Sand and/or Gravel
- Silt and/or Siltstone
- Claystone

25 feet
0
25 feet
No Vertical Exaggeration

NOTE: 1986 Well locations resurveyed during 1988.
This plate reflects new locations and elevations.

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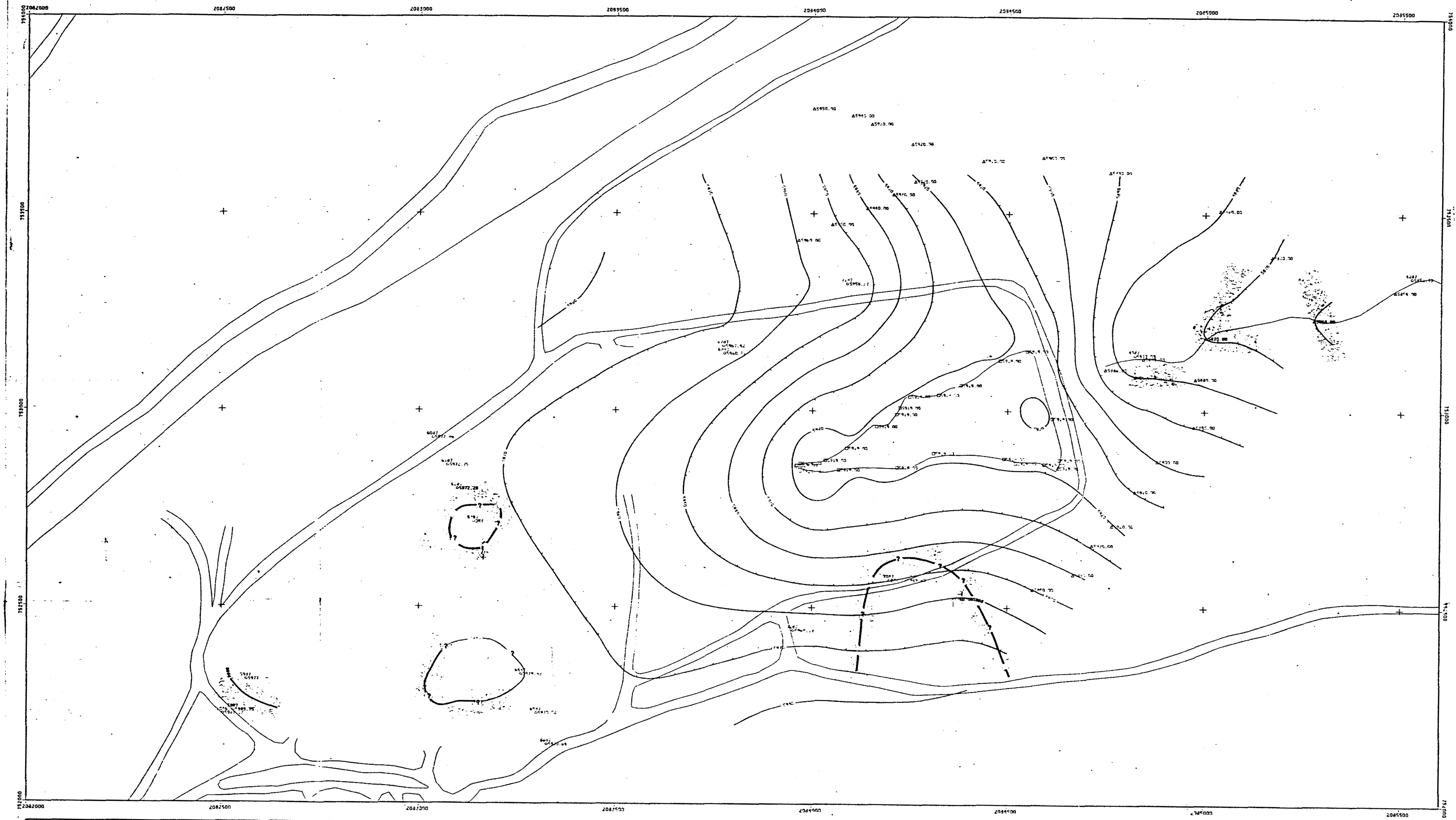
Plate 4-6

Landfill Area

CROSS SECTION D-D' &E-E'

July, 1988



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GOLDEN, COLORADO

PLATE 4-7:

WATER TABLE ELEVATIONS AT THE PRESENT LANDFILL FOR JANUARY 1988

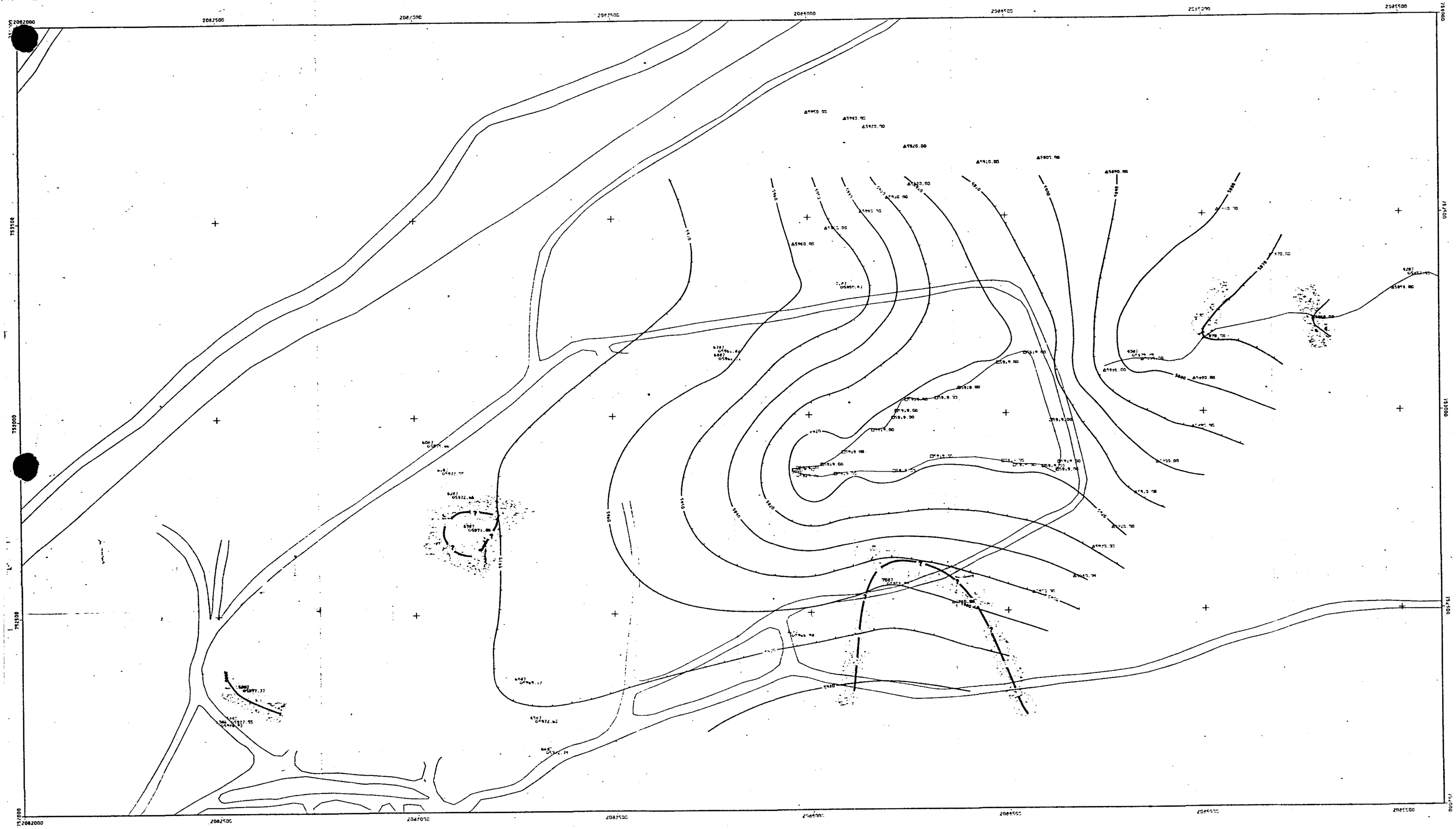
CONTOUR INTERVAL = 10 FT

SCALE 1 INCH = 100 FT

28 JUNE 1988

EXPLANATION

	MONITOR WELL LOCATION, WELL IDENTIFICATION, AND ELEVATION OF WATER TABLE (FEET ABOVE MSL).
▲	ELEVATION OF EPHEMERAL STREAM
o	WATER SURFACE ELEVATION
5000	LINES OF EQUAL WATER TABLE ELEVATION (FEET ABOVE MSL). HATCHURE LINES INDICATE FLOW DIRECTION.
	Areas of Unsaturated Surficial Materials



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GOLDEN, COLORADO

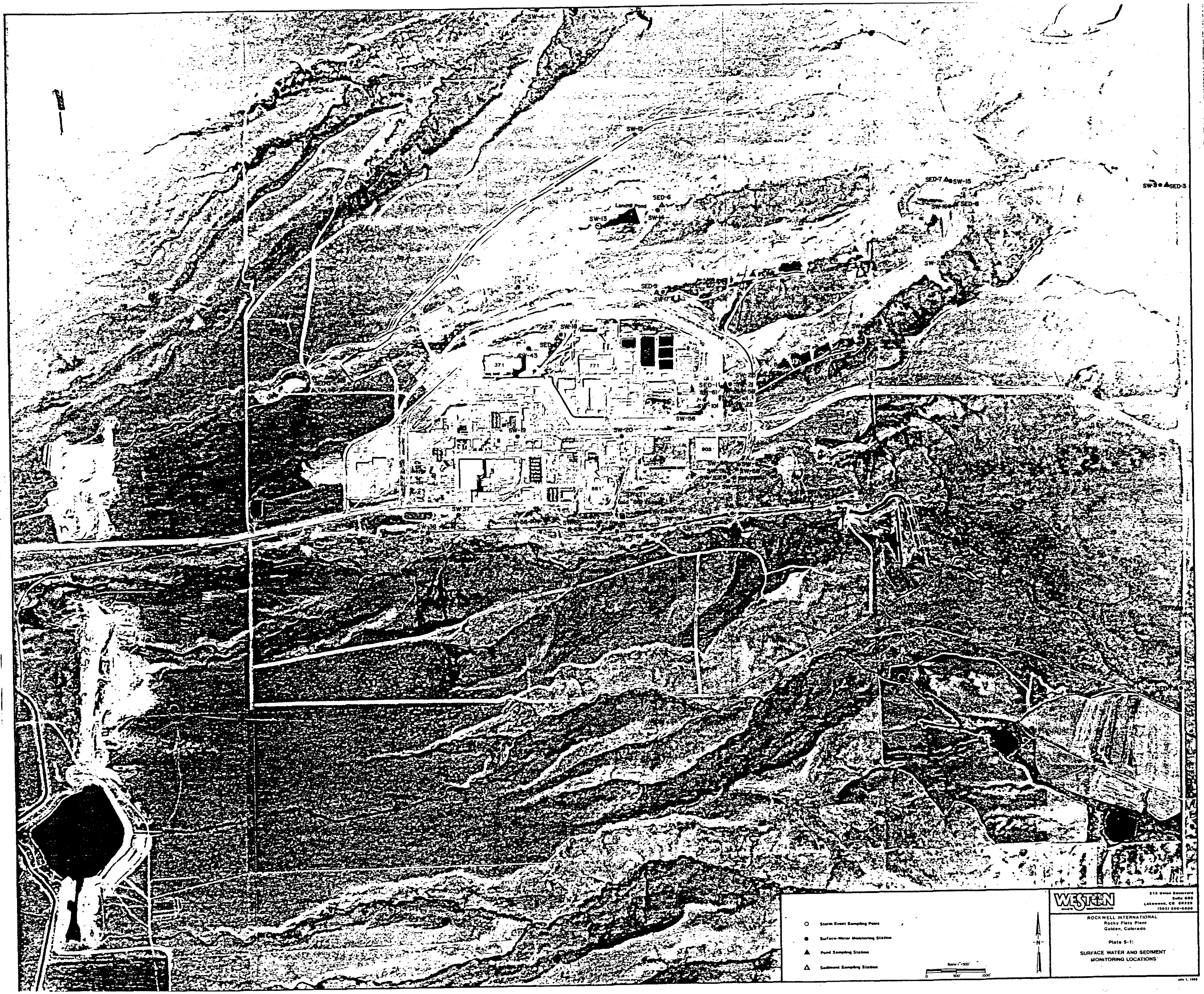
PLATE 4-8:

WATER TABLE ELEVATIONS AT THE
PRESENT LANDFILL FOR APRIL 1988

CONTOUR INTERVAL = 10 FT
SCALE 1 INCH = 100 FT
28 JUNE 1988

EXPLANATION

1086 ○ 15.21	MONITOR WELL LOCATION, WELL IDENTIFICATION, AND ELEVATION OF WATER TABLE (FEET ABOVE MSL).
△	ELEVATION OF EPHEMERAL STREAM
□	WATER SURFACE ELEVATION
5000	LINES OF EQUAL WATER TABLE ELEVATION (FEET ABOVE MSL). HATCHURE LINES INDICATE FLOW DIRECTION.
	Areas of Unsaturated Surficial Materials


SW-13
Landfill Pond
SED-6
SW-14
SED-7
SW-15
SED-8
SED-3
SED-9
SW-20
SW-56
SW-57
371
771
903
881
Storm Event Sampling Point
Surface-Water Monitoring Station
Pond Sampling Station
Sediment Sampling Station
Scale 1"=500'
0
500'
1000'
N
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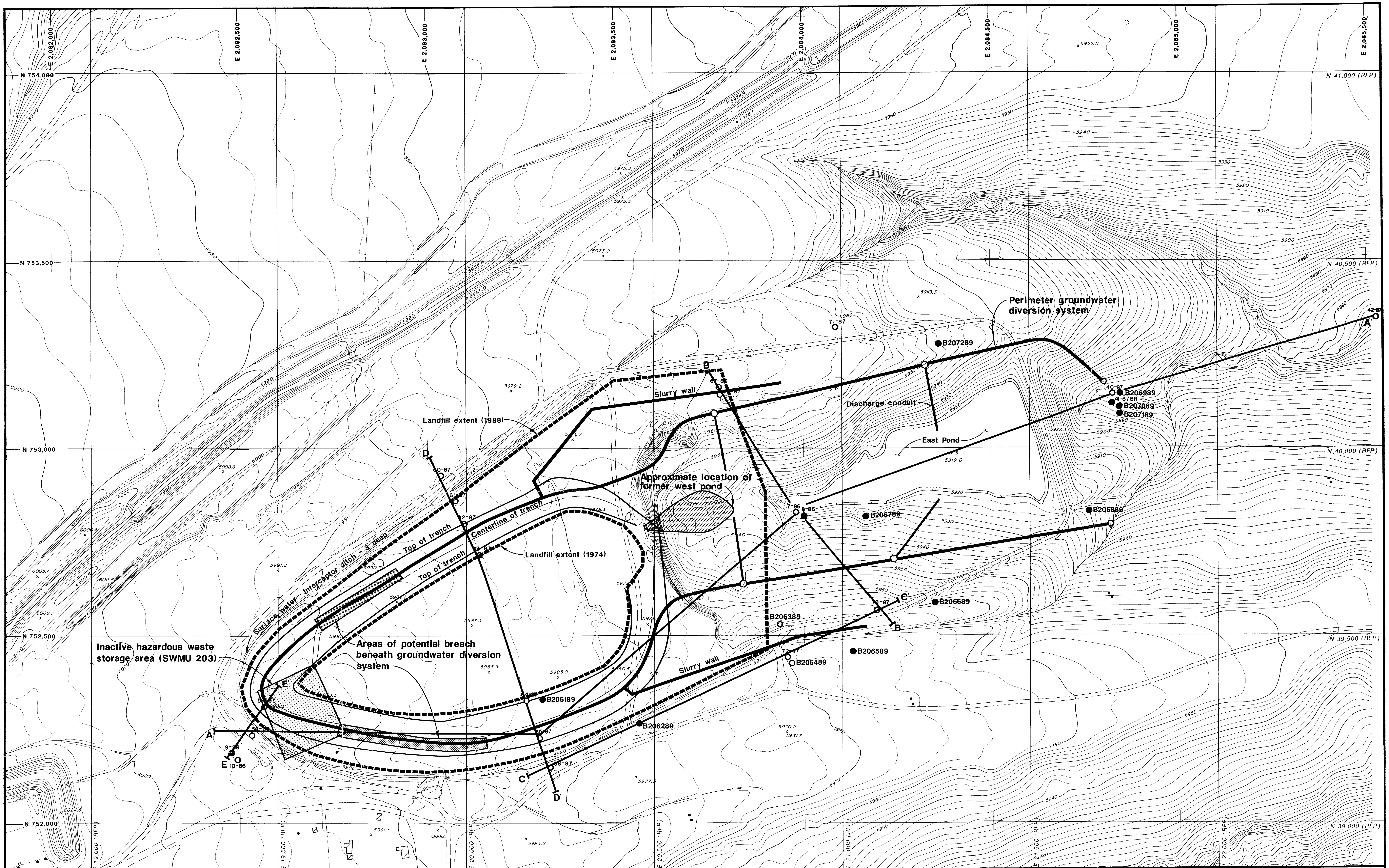
Lakewood, CO 80228
(303) 980-6800
ROCKWELL INTERNATIONAL
Rocky Flats Plant
Golden, Colorado
Plate 5-1:
SURFACE WATER AND SEDIMENT
MONITORING LOCATIONS



LEGEND

○ Alluvial monitoring well

● Bedrock monitoring well

⬡ Groundwater diversion system valves

EXPLANATION

Note: The base map for this plate shows 1986 topography and includes information from Plate 4-1 of the 1988 Present Landfill Hydrogeologic Characterization Report (Rockwell International 1988d). Locations of 1989 wells are from EG&G (1990a).

N

Scale: 1"=100'

100 0 100

Contour Interval = 2 feet

DRAWN BY: R.D.A.	DATE 5/4/90	CHECKED BY: A.F.C.	DATE 5/4/90
AS CONSTRUCTED — CORRECTIONS COMPLETE			
BY		DATE	

REVISIONS

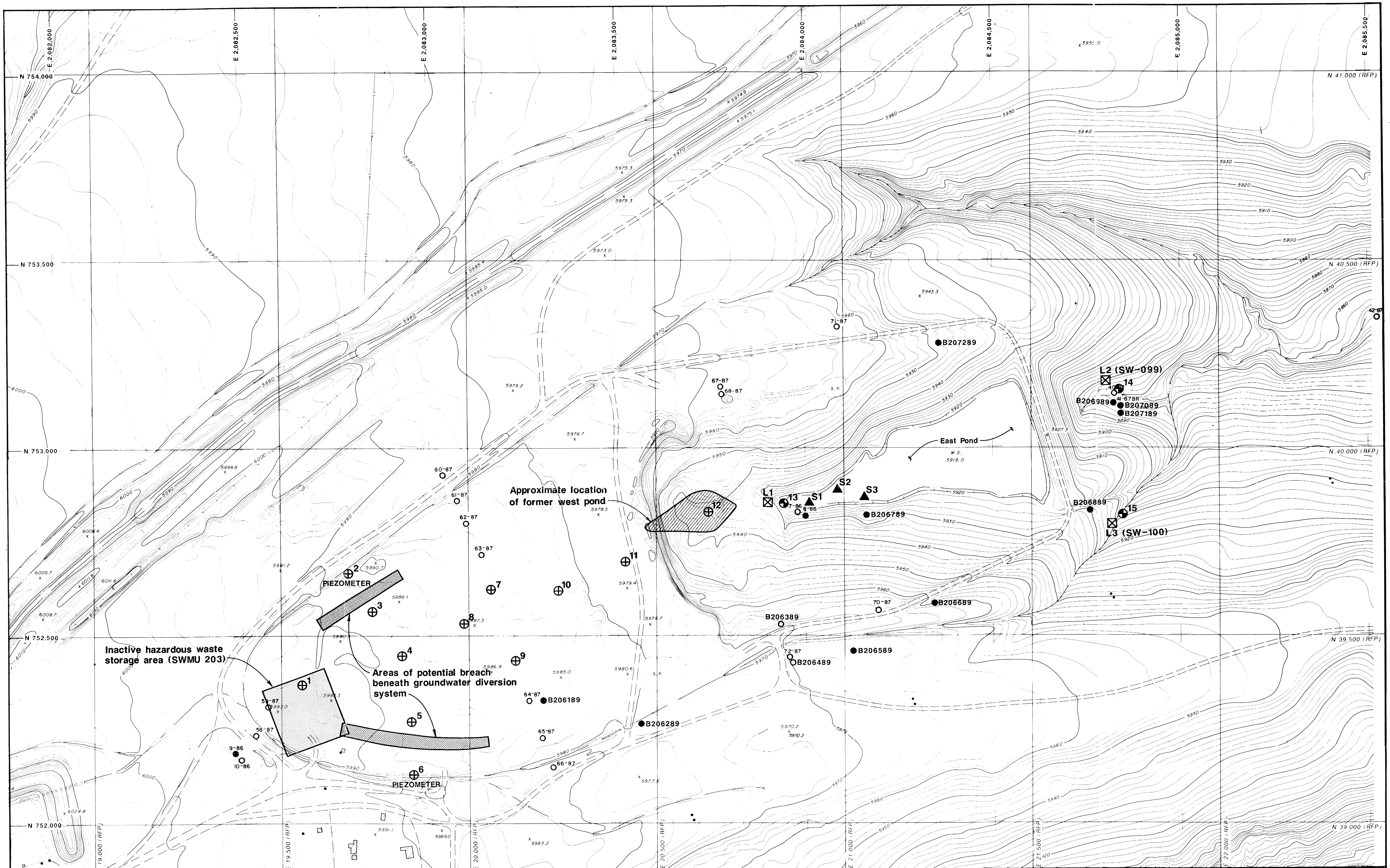
NO.	DESCRIPTION	DATE	BY
0	INITIAL DRAFT	4/6/90	A.F.C.
1	DRAFT FINAL	5/4/90	A.F.C.

PRESENT LANDFILL SITE PLAN, AND LOCATIONS OF WELLS AND SECTIONS

WOODWARD – CLYDE CONSULTANTS
Consulting Engineers Denver, Colorado

PHASE I RFI/RI WORK PLAN
PRESENT LANDFILL
ROCKY FLATS PLANT

DRAWING NO. OF
PLATE 2-1



EXPLANATION

LEGEND

- ⊕ Proposed boring to be completed as monitoring well or piezometer.
- Proposed boring to be grouted after completion.
- ⊠ Proposed surface water/leachate sampling location.
- ▲ Proposed sediment sampling location.
- ○ Existing alluvial monitoring well.
- ● Existing bedrock monitoring well.

Note: The base map for this plate shows 1986 topography and includes information from Plate 4-1 of the 1988 Present Landfill Hydrogeologic Characterization Report (Rockwell International 1988d). Locations of 1989 wells are from EG&G (1990a).

-N-

Scale: 1"=100'

100 0 100

Contour Interval = 2 feet

DRAWN BY: R.D.A.	DATE 5/4/90	CHECKED BY: A.F.C.	DATE 5/4/90
AS CONSTRUCTED — CORRECTIONS COMPLETE			
BY		DATE	

REVISIONS

NO.	DESCRIPTION	DATE	BY
0	INITIAL DRAFT	4/6/90	A.F.C.
1	DRAFT FINAL	5/4/90	A.F.C.

PROPOSED FIELD SAMPLING LOCATIONS
PHASE I RFI/RI

WOODWARD – CLYDE CONSULTANTS
Consulting Engineers — Denver, Colorado

PHASE I RFI/RI WORK PLAN
PRESENT LANDFILL
ROCKY FLATS PLANT

DRAWING NO. OF
PLATE 7-1